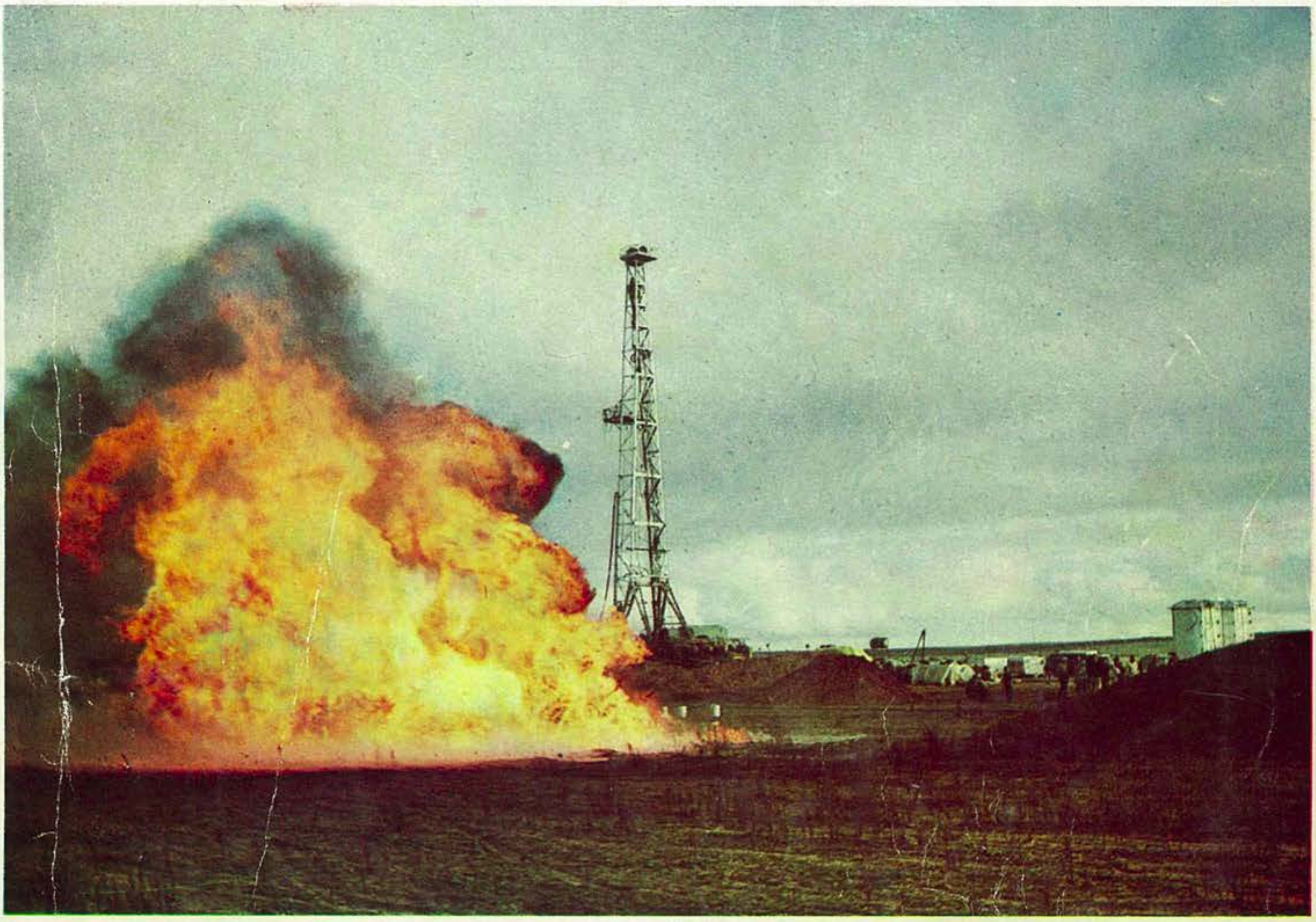
1964



Report of the DEPARTMENT OF MINES

WESTERN AUSTRALIA

PRESENTED TO BOTH HOUSES OF PARLIAMENT BY HIS EXCELLENCY'S COMMAND

REPORT OF THE DEPARTMENT *of* MINES WESTERN AUSTRALIA FOR THE YEAR 1964

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1965

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To the Hon. Minister for Mines.

Sir,

I have the honour to submit the Annual Report of the Department of Mines of the State of Western Australia for the year 1964, together with reports from the officers controlling Sub-Departments, and Comparative Tables furnishing statistics relative to the Mining Industry.

I have the honour to be, Sir,

Your obedient Servant,

A. H. TELFER,

Under Secretary for Mines.

Perth, 1965.

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STATE OF WESTERN AUSTRALIA

Report of the Department of Mines for the Year 1964

DIVISION I

The Honourable Minister for Mines:

I have the honour to submit for your information a report on the Mining Industry for the year 1964.

The estimated value of the mineral output of the State for the year was £A24,751,406, an increase of £A3,674,856 in value compared with that for the preceding year, and which also eclipsed by £A1,654,606 the previous all time record established in 1962, which in turn had culminated the sixth successive similar occurrence on that occasion.

The estimated value of gold received at the Perth Branch of the Royal Mint and exported in gold-bearing material was £A11,149,943, a further decline of £A1,367,743 when compared with last year, and equalled only 45.06 per cent. of all minerals for 1964.

Other minerals realised: Alumina (from Bauxite), £3,531,720; coal, £2,339,467; ilmenite, £1,538,175; pig iron (from iron ore) (for export), £1,270,189; asbestos, £1,105,781; iron ore (for pig), £1,101,608; tin £620,391; manganese, £457,338; pyrites (for sulphur), £368,782; copper ore and concentrates, £268,648; zircon, £195,637; silver, £143,841; cupreous ore and concentrates (fertiliser), £125,985; clays, £109,075; lead ore and concentrates, £92,632; talc, £75,002; monazite, £54,475; gypsum, £55,778; limestone, £42,650; rutile, £25,771; tanto/columbite ores and concentrates, £13,287; leucoxene, £11,894; magnesite, £10,020; felspar, £9,724; beryl, £9,037; copper (metallic by-product), £7,230; glass sand, £7,029; building stone, £5,814; lithium ores, £2,646; ochre, £1,941; scheelite, £1,174; and barytes, £683.

(See Tables 1 and 1 (a), Part II).

Coal Production from Collie during the year showed a tonnage increase of 9.41 per cent. with a slight decrease of 1.47 per cent. in the proportion of deep mine coal, but the overall average value per ton rose by 3.395 shillings per ton.

Figures for the last three years being:—

	1962	1963	1964
Tons	919,112	902,495	987,420
Total Value	£1,980,778	£1,985,060	£2,339,467
Average value per ton	43·102 sh.	43·990 sh.	47·385 sh
Average effective workers	757	757	76
Proportion of deep mined coal	65·12%	66·70%	65·23%

Minerals other than Gold and Coal rose sharply in value to £11,261,996, an increase of £4,688,192 above last year to establish a new all time record 46.64 per cent. higher than the previous figure set in 1962. This was mainly due to the first year value of the Alumina recovery from Bauxite and the expanding operations of the Mineral Beach Sands Industry, which also greatly exceeded its previous highest return in 1962 by 79.86 per cent.

Dividends paid by gold mining companies amounted to £1,656,828 a decline of £507,667 when compared with the previous year. (See Table 5, Part II).

To the end of 1964 the progressive total distributed by gold mining companies amounted to £72,608,236.

To the same date the progressive value of the whole mineral production of the State amounted to £626,489,425, of which gold amounted for £494,482,373. (See Table VI at back).

Gold

The quantity of gold advised as being received at the Perth Branch of the Royal Mint (709,776.09 fine ounces), together with that contained in gold-bearing material exported for treatment (3,070.91 fine ounces), totalled 712,847.00 fine ounces, which was 87,364.71 fine ounces less than the previous year. (See Table 1A of Part II).

The total gold yield reported directly to the Department by the producers was 715,481.11 fine ounces, a decrease of 87,378.67 fine ounces.

The variation between the two annual totals being principally due to the fact that the gold advised as being received at the Mint and contained in material exported for treatment, is not necessarily produced during the calendar year under review, a certain quantity being always in the transitory stage from the producer at the end of the year. The former total is accepted as the official gold production of the State on account of its realised monetary value, whilst the latter is utilised in tracing gold back to its source, i.e., individual mine production to which its respective ore tonnage can be applied, and so furnish a record of the physical aspect of mining so necessary and valuable for geological and professional purposes.

The tonnage of ore reported to have been treated in 1964, viz, 2,645,956 tons, was 124,210 tons less than the previous year, and constituted 61.65 per cent. of the State record tonnage established in 1940.

The following tonnage increases were reported from the respective Goldfields—Kimberley 60 tons, Gascoyne 131, East Murchison 798, Murchison 18,995, Broad Arrow 7,002, East Coolgardie 167,322 and South-West Mineral Field, 52; those fields showing a reduction in tonnage being Pilbara 511, Peak Hill 817, Yalgoo 161, Mt. Margaret 159,998, North Coolgardie 68, North East Coolgardie 304, Coolgardie 25,197, Yilgarn 123,964 and Dundas, 7,327 tons.

In the East Coolgardie Goldfield a rise of 167,322 tons brought the total quantity of ore treated there during the year to a new record of 2,207,827 tons topping the previous 1960 record by 138,662 tons.

The famous "Golden Mile" locality of Kalgoorlie-Boulder mining centres contained in this Goldfield has to date treated 84.73 million tons of ore for 35.62 million fine ounces of gold (equivalent to 1,082.21 tons of the precious metal itself), valued at a progressively estimated £A274.48 million. These figures represent 56.47 per cent. of the State's reported ore tonnage and 56.22 per cent. of its gold.

At the peak of its gold production in 1903 there were 42 companies actively producing on the "Golden Mile." This number has been gradually reduced to the four large companies now in operation.

The increased tonnage of 167,322 reported from the Goldfield during the year was due to the expanding operation of Gold Mines of Kalgoorlie (Aust.) Ltd. with an extra 57,102 tons from their main leases, 115,703 additional tons from their highly mechanised low grade group at Mt. Charlotte, and a trial of 10,712 tons from the low grade Kalgoorlie Star lease. An even grade of ore was maintained from the principal leases of the Company.

Slightly lower tonnages of 24,957 and 7,049 respectively were reported by Great Boulder Gold Mines Ltd. and Lake View and Star Ltd., whilst the North Kalgurli (1912) Ltd. output rose by 7,663 tons.

Although the Murchison Goldfield showed an increase of 18,995 tons in its output there was a decline of 12,286 fine ounces in the gold production. This was occasioned by the 22,674 higher tonnage reported by Hill 50 Gold Mine N.L., whose grade of ore treated dropped to 7.510 dwts. per ton from the previous year's average of 9.621 dwts. per ton. The effects of the prior closure of the Eclipse Gold Mines were also noticeable.

The decline in the Mt. Margaret, Yilgarn and Coolgardie Goldfields was caused by the cessation of the Sons of Gwalia Ltd., Great Western Consolidated N.L. and the Paris Gold Mines Ltd. respectively, assisted by the withdrawal of Gold Mines of Kalgoorlie (Aust.) Ltd. from the latter field where it had been operating the Bayley's South mine.

Broad Arrow Goldfield recorded a 7,002 tons improvement as a result of expanded low grade operations on the Gimlet South Leases.

Central Norseman Gold Corporation N.L. was virtually responsible for the variation in the Dundas Goldfield figures for the year, and although treating 7,434 tons less, their grade of ore showed a slight improvement from 10.854 to 11.038 dwts. per ton.

The gold mining industry is still labouring under the burden of producing a valuable static priced commodity whilst faced by constantly rising costs.

A considerable difficulty is experienced under such adverse circumstances by the larger companies in proving and maintaining sufficiently payable reserves to preserve the life-span of their mines, and an existing employment problem could be further aggravated by the counter development of other minerals in the near future.

The preservation of such a national asset as the gold mining industry would appear most desirable, especially in view of the nation's brighter economic prospects in regard to future trade expansion.

Any or every effort to encourage or stimulate its retention or solve its problems would therefore be viewed with more than considerable interest.

West Australian gold included in sales on open dollar markets by the Gold Producers' Association Ltd. for the period from September 1963 to June 1964, totalled 556,658.18 fine ounces; the extra premium received therefrom in excess of Mint Value amounted to £A11,709, and overall average of 5.048 pence per fine ounce. This amount, less expenses, was distributed to the producer members during the year and approximated 4.508 pence per fine ounce.

Subsidy payments made by the Commonwealth Government during the year under the Gold Mining Subsidy Act, 1954-1962, totalled £541,702, a decrease of £128,517 in comparison with the previous year. Of the amount distributed, £511,885 went to Large Producers, and £28,817 to Small Producers in this State.

COMPARATIVE MINERAL STATISTICS.

——	1963	1964	Variation
GOLD—			
Reported to Department (Mine Production)—			
Ore (tons)	2,770,166	2,645,956	— 124,210
Gold (fine ounces)	802,860	715,481	— 87,379
Average Grade (dwts. per ton)	5·796	5·408	— 0·338
Persons Engaged—			
(a) Effective Workers (excluding absentees)	4,901	4,383	— 518
(b) Total Pay Roll	5,297	4,785	— 512
Dividends (£A)	2,164,495	1,656,828	— 507,667
Mint and Export (Realised Production)—			
Gold (fine ounces)	800,212	712,847	— 87,365
Estimated Value (£A) (including Overseas Gold Sales Premium)	12,517,686	11,149,943	—1,367,743
COAL—			
Reported to Department (Mine Production)—			
Tons	902,495	987,420	+ 84,925
Value (£A)	1,985,060	2,339,467	+ 345,407
Persons Engaged—			
Effective Workers (excluding absentees)	757	765	+ 8
OTHER MINERALS—			
Reported to Department—			
Value (£A)	6,573,804	*11,261,996	+4,688,192
Persons Engaged—			
Effective Workers (excluding absentees)	1,534	1,870	+ 336
TOTAL ALL MINERALS—			
Value (£A)	21,076,550	*24,751,406	+3,674,856
Persons Engaged—			
Effective Workers†	7,192	7,018	— 174

* All time record.

† Excluding Oil Search Men which engaged an average of 239 men in the field in 1963 and 257 men in the field in 1964.

PART II—MINERALS.

During the year Royalty totalling £184,038 as against £115,649 for the previous year, was collected under legislation passed in 1958 on certain prescribed minerals obtained from land held under the Mining Act.

Gold was exempted from royalty liability, and payment on Copper, Lead and Mineral Beach Sands, temporarily suspended on account of depressed marketing conditions, etc., but partially reimposed on the latter during the current year.

Royalty has been collected on Coal practically from inception of production and on Iron Ore (for Export), from 1951.

Particulars for the year are shown hereunder:—

Mineral	Amount Per Ton s. d.	Royalty Collected. £ s. d.
Asbestos	1 6	891 3 6
Barytes	6	2 16 0
Bauxite	6	10,412 12 1
Bentonite	6	5 18 0
Beryl	2 0	9 0 0
Building Stone	1 0	65 12 0
Clay	6	1,432 2 7
Coal	3	13,233 15 6
Felspar	6	34 0 6
Fullers Earth	6	2 17 0
Glass Sands	6	252 14 0
Gypsum	6	1,156 7 5
Iron Ore	1 6	147,017 14 0
Ilmenite	† 6	2,960 3 6
Lepidolite	1 0	3 0
Leucoxene	† 6	2 0 0
Limestone	6	789 0 6
Magnesite	1 6	136 13 9
Manganese	1 6	2,273 12 0
Monazite	† +	75 19 0
Mineral Phosphates	1 0	16 0
Ochre	6	5 0
Petalite	1 0	12 0 0
Pyrites	1 0	2,931 8 0
Rutile	† 9	25 1 9
Scheelite	*	5 7 5
Tanto/Columbite	*	12 18 1
Tin	2 0	95 19 2
Zircon	† 6	200 11 0
		£184,038 10 9

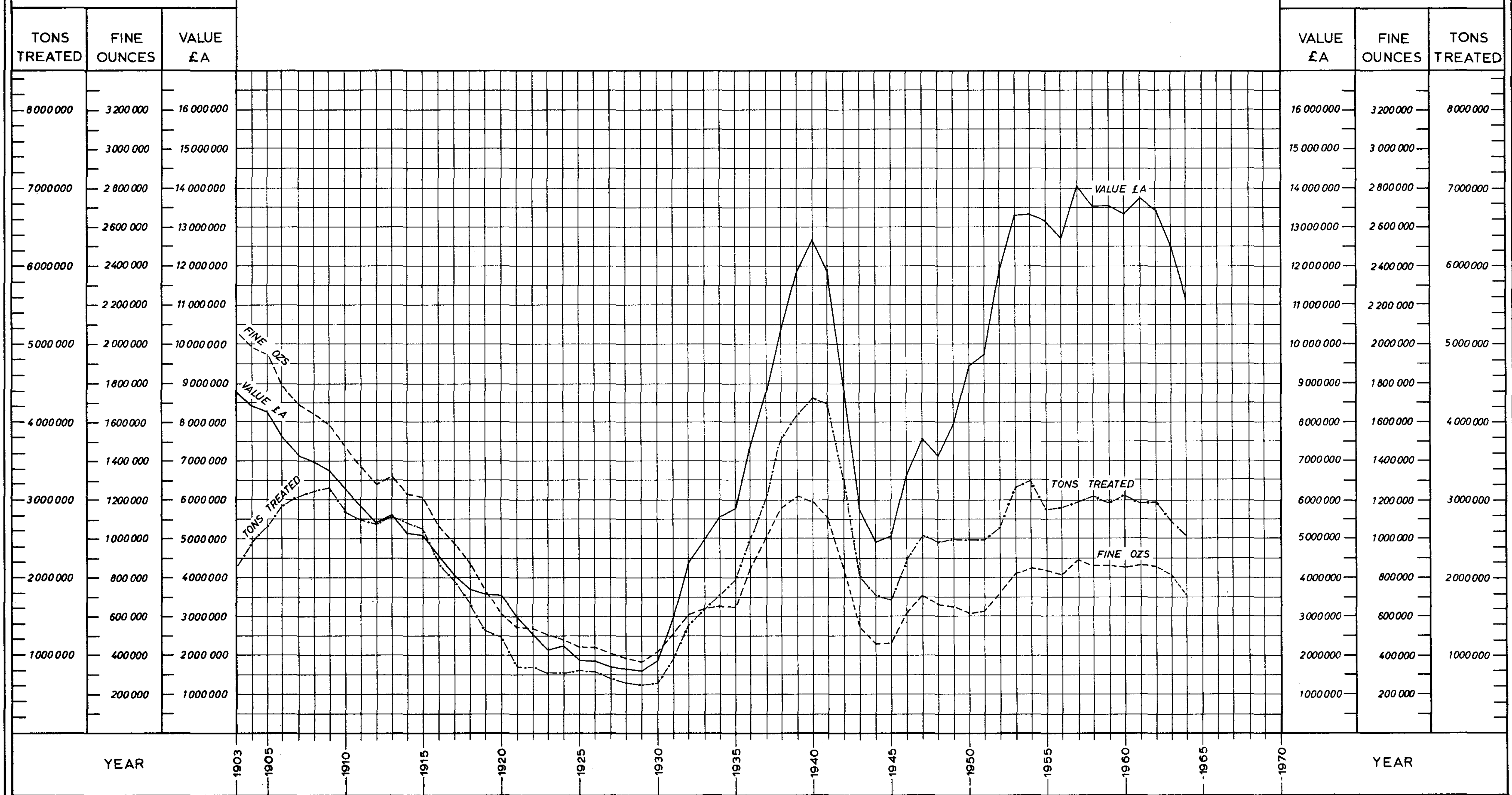
* One-half per centum of realised F.O.B. value.

\+ One-quarter per centum of realised F.O.B. value.

† Half rate for year.

DIAGRAM OF GOLD OUTPUT

SHOWING TONNAGES TREATED AS REPORTED TO MINES DEPT., THE TOTAL OUTPUT OF GOLD BULLION CONCENTRATES ETC. ENTERED FOR EXPORT AND RECEIVED AT THE PERTH MINT AND THE ESTIMATED VALUE THEREOF IN AUSTRALIAN CURRENCY



As a result of the extensive exploration for iron ore the State's iron ore reserves have been assessed at over 15,000 million tons of good grade ore.

During the calendar year 1964 contracts were signed with Japanese steel interests for the supply of iron ore from Tallering Peak, Mt. Goldsworthy and Hamersley Ranges (Mt. Tom Price) amounting in all to 87 million tons over the next 22 years. Further agreements are being negotiated with Japanese interests for more large tonnages from several other deposits. These contracts will entail the building of new townsites at the mining areas and at the port sites and the construction of standard gauge railways from the mines to the ports. The up-grading of Port Hedland as a port to provide for large ore carriers and the building of at least one new port to be situated in King Bay constitute further developments in the North West resulting from the exploitation of our iron ore deposits.

Our mineral resources continue to attract worldwide interest and numerous large overseas organisations and several local companies are carrying out expensive exploratory programmes by the most modern scientific methods. These organisations are interested particularly in the search for gold, copper, iron, phosphates and tin.

Full production of alumina from the Darling Range bauxite deposits has now been reached and during the year 1964 the value of alumina produced amounted to £3,531,720.

Mineral beach sands production has now been satisfactorily established and during the year under review the value of beach sands amounted to £1,825,952.

Preparations for the production of tin from Greenbushes by Greenbushes Tin N.L. are proceeding satisfactorily and it is anticipated that the dredge will be in operation in 1965.

Australian Blue Asbestos has been carrying on an exploration programme with assistance from the Mines Department in the Wittenoom and Yampire gorges for reserves of fibre.

There has been more interest in our manganese deposits during the year.

Renewed interest has been shown in the tin deposits in the Pilbara Goldfields and several companies have carried out some exploration of the Pilbara deposits. Kathleen Investments have also acquired the areas held by Mineral Concentrates Ltd. and propose to carry out extensive operations in the area.

There was a slight increase in the lead mining activities in the Northampton Mineral Field resulting from the rise in the price of lead.

COAL.

During the year ended 31st December, 1964, the coal production amounted to 987,420 tons, an increase of 84,925 tons compared with last year's figure.

The coal contracts continue to operate satisfactorily and production fluctuates entirely in accordance with the demand.

OIL.

Once again the search for oil has been intensified this year with farm-outs to several experienced companies. In addition to exploration on land a number of applications have been received for permits to explore on the off-shore areas of the continental shelf. Operations both on land and off-shore include geophysical, geological and magnetometer surveys, and some deep drilling.

The discovery of oil and gas in the wells at Yardarino and Barrow Island this year have given great encouragement and impetus to the local seach for oil.

WATER.

As a result of the Commonwealth Government's legislation giving assistance to the States in the exploration of their underground water resources there has been increased activity and the Department's hydrological section has expanded its exploration programme. At the same time assistance has been given to other Government Departments, local authorities and private persons to establish water supplies for specific requirements.

TABLE 1

Quantity and Value of Minerals, other than Gold and Silver, produced during Years 1963 *and* 1964

Western Australia

Description of Minerals	1963		1964		Increase or Decrease for Year compared with 1963	
	Quantity	Value	Quantity	Value	Quantity	Value
	Tons	£A	Tons	£A	Tons	£A
Alumina (from Bauxite)	....	....	370,784·00	3,531,720	+ 370,784·00	+ 3,531,720
Asbestos (Chrysotile)	10·13	783	536·19	43,681	+ 526·06	+ 42,898
(Crocidolite)	11,094·57	1,202,002	10,614·14	1,062,100	— 480·43	— 139,902
Barytes	....	....	171·70	683	+ 171·70	+ 683
Beryl	82·03	11,102	79·84	9,037	— 2·19	— 2,065
Building Stone* (Granite—Facing Stone)	82·00	2,160	33·00	600	— 49·00	— 1,560
(Lepidolite)	....	....	8·35	73	+ 8·35	+ 73
(Prase)	....	....	9·50	138	+ 9·50	+ 138
(Quartz—Dead White)	....	....	115·00	865	+ 115·00	+ 865
(Sandstone)	....	....	72·00	216	+ 72·00	+ 216
(Sandstone—Donnybrook)	83·00	1,743	....	....	— 83·00	— 1,743
(Slate)	....	....	50·00	300	+ 50·00	+ 300
(Spongolite)	394·00	1,874	771·00	3,622	+ 377·00	+ 1,748
Clays (Bentonite)	1,197·00	3,875	676·28	1,571	— 520·72	— 2,304
(Cement Clay)	18,772·00	15,109	27,350·00	27,990	+ 8,578·00	+ 12,881
(Fireclay)	25,001·50	26,088	47,251·50	43,036	+ 22,250·00	+ 16,948
(Fuller's Earth)....	....	....	114·00	456	+ 114·00	+ 456
(Kaolin)	125·24	285	61·35	137	— 63·89	— 148
(White Clay-Ball Clay)	794·00	3,101	570·00	2,258	— 224·00	— 843
(Brick, Pipe and Tile Clay)*	56,607·00	63,551	28,715·00	33,627	— 27,892·00	— 29,924
Coal	902,494·00	1,985,060	987,419·70	2,339,467	+ 84,925·20	+ 354,407
Copper (Metallic By-Product)‡	76·98	13,918	46·14	7,230	— 30·84	— 6,688
Copper Ore and Concentrates	5,860·02	290,120	4,324·93	268,648	— 1,535·09	— 21,472
Cupreous Ore and Concentrates (Fertiliser)	3,234·75	136,200	2,196·69	125,985	— 1,038·06	— 10,215
Felspar	992·00	6,985	1,386·00	9,763	+ 394·00	+ 2,778
Glass Sand	9,926·09	7,555	10,047·00	7,029	+ 120·91	— 526
Gypsum	50,808·28	82,467	44,998·12	53,778	— 5,810·16	— 28,689
Iron Ore (Pig Iron recovered)	46,038·00	1,036,074	47,906·00	1,101,608	+ 1,868·00	+ 65,534
(Ore Exported)	1,277,613·00	1,266,967	1,280,864·00	1,270,189	+ 5,251·00	+ 3,222
Lead Ores and Concentrates	184·93	6,535	3,354·17	92,632	+ 3,169·24	+ 86,097
Limestone*	27,895·63	33,618	31,639·00	42,650	+ 3,743·37	+ 9,032
Lithium Ores (Petalite)	390·02	3,709	208·00	1,591	— 182·02	— 2,118
(Spodumene)	22·00	270	51·54	1,055	+ 29·54	+ 785
Magnesite	6,494·53	44,167	1,574·24	10,020	— 4,920·29	— 34,147
Manganese (Metallurgical, Battery and Low Grades)	39,356·96	512,995	38,823·81	457,338	— 533·15	— 55,657
Mineral Beach Sands (Ilmenite)	136,879·93	682,067	330,832·70	1,538,175	+ 193,952·77	+ 856,108
(Monazite)	1,048·81	43,339	1,317·19	54,475	+ 268·38	+ 11,136
(Rutile)	606·00	18,034	825·51	25,771	+ 219·51	+ 7,737
(Leucoxene)	460·00	5,983	643·19	11,894	+ 183·19	+ 5,911
(Zircon)	4,572·85	45,802	20,068·72	195,637	+ 15,495·87	+ 149,835
Ochre (Red)	212·80	1,278	323·51	1,941	+ 110·71	+ 663
Phosphatic Guano	16·00	160	....	....	— 16·00	— 160
Pyrites Ore and Concentrates (For Sulphur)	58,472·31	384,875	58,396·00	368,782	— 76·31	— 16,093
Quartz Grit	56·00	43	....	....	— 56·00	— 43
Talc	4,669·15	71,213	5,431·69	75,002	+ 762·54	+ 3,789
Tanto/Columbite Ores and Concentrate	13·79	23,234	14·57	13,287	+ ·78	— 9,947
Tin	576·23	408,023	637·04	620,391	+ 60·81	+ 212,368
Tungsten Ores and Concentrate—Scheelite	....	....	4·31	1,174	+ 4·31	+ 1,174
Total	....	8,442,364	....	13,457,622	....	+ 5,015,258

TABLE 1 (A)

Quantity and Value of Gold and Silver Exported and Minted during Years 1963 *and* 1964

Description of Minerals	1963		1964		Increase or Decrease for Year compared with 1963	
	Quantity	Value	Quantity	Value	Quantity	Value
	Fine Oz.	£A	Fine Oz.	£A	Fine Oz.	£A
Gold (Exported and Minted)....	800,211·71	†12,517,686	712,847·00	†11,149,943	— 87,364·71	— 1,367,743
Silver (Exported and Minted)	203,093·18	116,500	245,557·97	143,841	+ 42,464·79	+ 27,341
Total	....	12,634,186	....	11,293,784	....	— 1,340,402
Grand Total	....	21,076,550	....	24,751,406	....	+ 3,674,856

* Incomplete—figures relate only to production reported to the Department from holdings under the Mining Act.

† Including Overseas Gold Sale Premium.

‡ By-Product of Gold Mining.

TABLE 2

Showing for every Goldfield the amount of Gold reported to the Mines Department as required by the Regulations, also the percentage for the several Goldfields of the total reported and the average value of the yield in pennyweights per ton of ore treated

Goldfield	Reported Yield		Percentage for each Goldfield		Average Yield per ton of ore treated	
	1963	**1964**	1963	**1964**	1963*	**1964***
	Fine oz.	Fine oz.	Per cent.	Per cent.	Dwts.	Dwts.
1. Kimberley	160	**16**	·020	**·002**	26·667	**5·333**
2. West Kimberley	....	....	....	....	....	....
3. Pilbara	1,764	**968**	·220	**·135**	18·251	**13·615**
4. West Pilbara	....	....	....	....	....	....
5. Ashburton	....	**1**	....	....	....	....
6. Gascoyne	241	**311**	·030	**·044**	38·871	**40·129**
7. Peak Hill	87	**18**	·011	**·003**	2·130	....
8. East Murchison	278	**847**	·035	**·119**	10·549	**12·614**
9. Murchison	83,701	**71,414**	10·425	**9·981**	9·785	**7·514**
10. Yalgoo	101	....	·013	....	12·547	....
11. Mt. Margaret	31,982	**909**	3·983	**·127**	3·911	**7·169**
12. North Coolgardie	18,356	**17,858**	2·286	**2·496**	10·511	**10·246**
13. Broad Arrow	1,285	**3,027**	·160	**·423**	3·053	**3·926**
14. North-East Coolgardie	232	**173**	·029	**·024**	7·607	**11·344**
15. East Coolgardie	531,102	**509,984**	66·151	**71·279**	5·206	**4·620**
16. Coolgardie	10,139	**4,008**	1·263	**·560**	6·824	**17·735**
17. Yilgarn	17,904	**2,784**	2·230	**·389**	2·780	**11·485**
18. Dundas	102,951	**100,864**	12·823	**14·097**	10·846	**11·053**
19. Phillips River	†2,542	**†2,210**	·317	**·309**	....	....
20. South-West Mineral Field	33	**87**	·004	**·012**	38·824	**25·217**
21. State Generally	2	**2**	....	....	....	....
	802,860	**715,481**	100·000	**100·000**	5·796	**5·408**

The total yield of the State is shown in Table 1, being the amount of gold received at the Royal Mint, the gold exported in bullion and concentrates and alluvial and other gold not reported to the Mines Department.

When comparisons are made as to the yield from any particular Field with the preceding year, the figures reported to the Department are used.

* Gold at £A15 12s. 6d. per fine ounce or 15s. 7½d. per pennyweight.

† By-product of Copper Mining.

TABLE 3

Output of Gold from the Commonwealth of Australia during 1964

State	Output of Gold	Value*†	Percentage of Total
	Fine oz.	£A	%
Western Australia	712,847	11,138,234	74·219
Victoria	21,252	332,063	2·213
New South Wales	10,543	164,734	1·098
Queensland	101,932	1,592,688	10·613
Tasmania	31,551	492,984	3·285
South Australia	17	266	·002
Northern Territory	82,317	1,286,203	8·570
Total	960,459	15,007,172	100·000

* £A15 12s. 6d. per fine ounce.

† Exclusive of Overseas Gold Sales Premium by Gold Producers' Association.

TABLE 4

Dividends, etc., paid by Western Australian Gold Mining Companies during 1964, *and the total to date*
(Compiled from information published by the Stock Exchanges of Sydney, Melbourne, Adelaide and Perth)

Goldfield	Name of Company	Dividends Paid	
		1964	Grand Total to end of 1964
		£	£
Pilbara	Various Companies	....	26,513
Peak Hill	do. do.	....	199,305
East Murchison	do. do.	....	1,914,053
Murchison	Hill 50 Gold Mine N.L.	300,000	7,665,626
	Various Companies	....	2,832,145
Mt. Margaret	do. do.	....	3,033,336
North Coolgardie	Moonlight Wiluna G.M.s Ltd.	....	127,500
	Various Companies	....	712,551
Broad Arrow	do. do.	....	92,500
North-East Coolgardie	do. do.	....	129,493
East Coolgardie	Gold Mines of Kalgoorlie (Aust.) Ltd.	153,234	3,230,437
	Great Boulder G.M.s Ltd.	153,125	9,743,775
	Lake View & Star Ltd.	350,000	(b) 11,030,750
	North Kalgurli (1912) Ltd.	180,469	3,439,218
	Various Companies	....	(a) 19,496,816
Coolgardie	do. do.	....	410,000
Yilgarn	do. do.	....	(c) 1,205,556
Dundas	Central Norseman Gold Corporation N.L.	520,000	6,532,500
	Various Companies	....	786,162
	Totals	1,656,828	72,608,236

(*a*) Excluding £45,091 in bonuses and profit-sharing notes in years 1935–1936 by Boulder Perseverance Ltd., and £55,000 Capital returned in year 1932 and £43,000 in bonuses and profit-sharing notes in the year 1934 by Golden Horseshoe (New) Ltd.

(*b*) Excluding £75,000 in bonuses and profit-sharing notes and £93,750 Capital returned in 1932–1935.

(*c*) Excluding £67,725 Capital returned by Edna May (W.A.) Amalgamated, N.L.

TABLE 5

Total Coal output from Collie River Mineral Field, 1963 *and* 1964, *estimated Value thereof, Number of Men employed, and output per Man as reported Monthly*

Year	Total Output	Estimated Value	Men Employed			Output per Man Employed		
			Above Ground	Under Ground	Above and Under Ground	Above Ground	Under Ground	Above and Under Ground
Deep Mining—	Tons	£A	No.	No.	No.	Tons	Tons	Tons
1963	600,934	1,570,551	136	517	653	4,418	1,162	920
1964	644,107	1,807,333	136	519	655	4,736	1,241	983
Open Cut Mining—								
1963	301,561	414,509	104	....	104	2,899	....	2,899
1964	343,313	532,134	110	....	110	3,121	....	3,121
Totals—								
1963	902,495	1,985,060	240	517	757	3,760	1,742	1,192
1964	987,420	2,339,467	246	519	765	4,014	1,903	1,291

PART III—LEASES AND OTHER HOLDINGS UNDER VARIOUS ACTS RELATING TO MINING.

TABLE 6

MINING ACT 1904.

Total Number and Acreage of Mining Tenements applied for during 1964 *and in force as at* 31*st December,* 1964 (*Compared with* 1963)

—	Applied for				In Force			
	1963		1964		1963		1964	
	No.	Acreage	No.	Acreage	No.	Acreage	No.	Acreage
Gold—								
Gold Mining Leases	84	1,488	79	1,433	989	18,253	953	17,716
Dredging Claims	1	300	....	....	2	312	2	312
Prospecting Areas	398	6,915	489	8,526	373	6,381	389	6,660
Temporary Reserves	12	3,005	346	117,097	80	23,155	342	115,390
Totals	495	11,708	914	127,056	1,444	48,101	1,686	140,078
Coal—								
Coal Mining Leases	25	7,418	8	2,319	72	21,229	66	19,529
Prospecting Areas	....	....	....	....	....	....	....	....
Temporary Reserves	....	....	....	....	1	1,600,000	3	3,020,800
Totals	25	7,418	8	2,319	73	1,621,229	69	3,040,329
Other Minerals—								
Mineral Leases	62	1,300	63	8,946	133	3,773	169	10,640
Dredging Claims	56	9,869	165	21,916	148	10,905	235	22,444
Mineral Claims	251	38,419	171	21,800	929	98,155	1,096	103,814
Prospecting Areas	76	1,570	85	1,854	70	3,764	80	1,759
Temporary Reserves	74	33,372,160	59	24,347,004	177	151,360,160	153	33,480,754
Totals	519	33,423,318	543	24,401,520	1,457	151,476,757	1,733	33,619,411
Other Holdings—								
Miner's Homestead Leases	5	85	9	954	309	33,530	346	33,552
Miscellaneous Leases	15	133	8	2,865	110	1,674	118	1,723
Residence Areas	2	1	2	1	73	28	71	23
Business Areas	2	2	....	....	27	23	27	22
Machinery Areas	1	3	4	18	29	83	28	77
Tailings Areas	2	8	2	8	23	90	25	99
Garden Areas	4	9	1	1	81	253	71	223
Quarrying Areas	2	39	3	72	7	73	10	146
Water Rights	5	38	7	30	118	2,442	134	2,499
Licenses to Treat Tailings	39	....	33	....	46	....	25	....
Total	77	318	69	3,949	823	38,196	855	38,364
Grand Totals	1,116	33,442,762	1,534	24,534,844	3,797	153,184,283	4,343	36,838,182

TABLE 6 (a)

SPECIAL ACTS

Total Number and Acreage of Mining Leases applied for during 1964 *and in force at* 31*st December,* 1964 (*Compared with* 1963)

Holding	Applied for				In Force			
	1963		1964		1963		1964	
	No.	Acreage	No.	Acreage	No.	Acreage	No.	Acreage
Mineral Leases	....	....	1	10,240	2	1,817,111	2	1,817,111

TABLE 6 (b)

PETROLEUM ACT

Total Number and Acreage of Permits to Explore and Licenses to Prospect applied for during 1964 *and in force at* 31*st December,* 1964 (*Compared with* 1963)

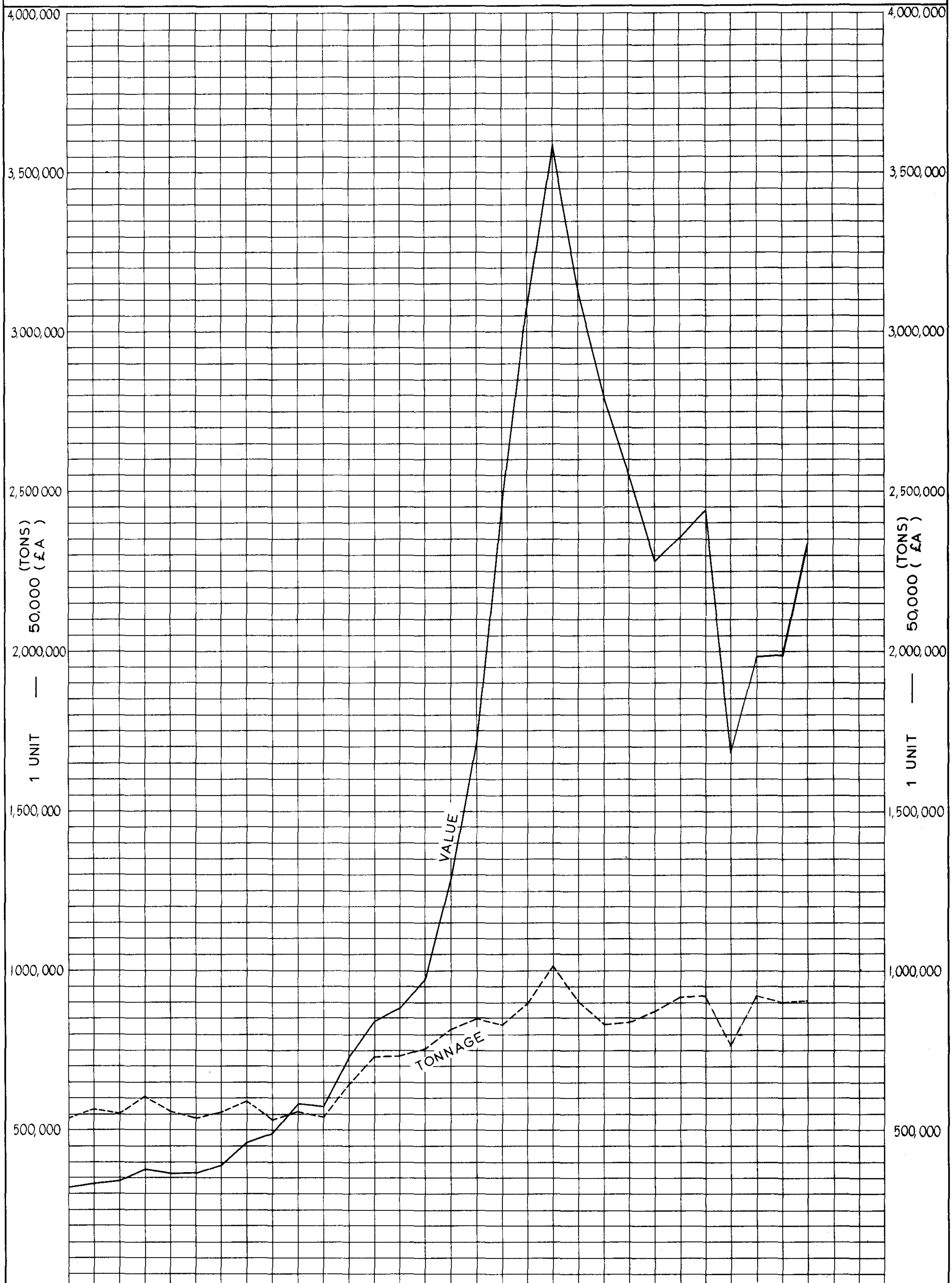
Holding	Applied for				In Force			
	1963		1964		1963		1964	
	No.	Acreage	No.	Acreage	No.	Acreage	No.	Acreage
Permits to Explore	10	131,499,520	12	112,652,800	37	436,272,000	46	525,139,840
Licenses to Prospect	5	636,800	20	2,019,200	49	5,523,200	37	4,462,760
Totals	15	132,136,320	32	114,672,000	91	441,795,200	83	529,602,600

Total Area of Leases Applied for, Approved and in Force as at 31st December, 1964

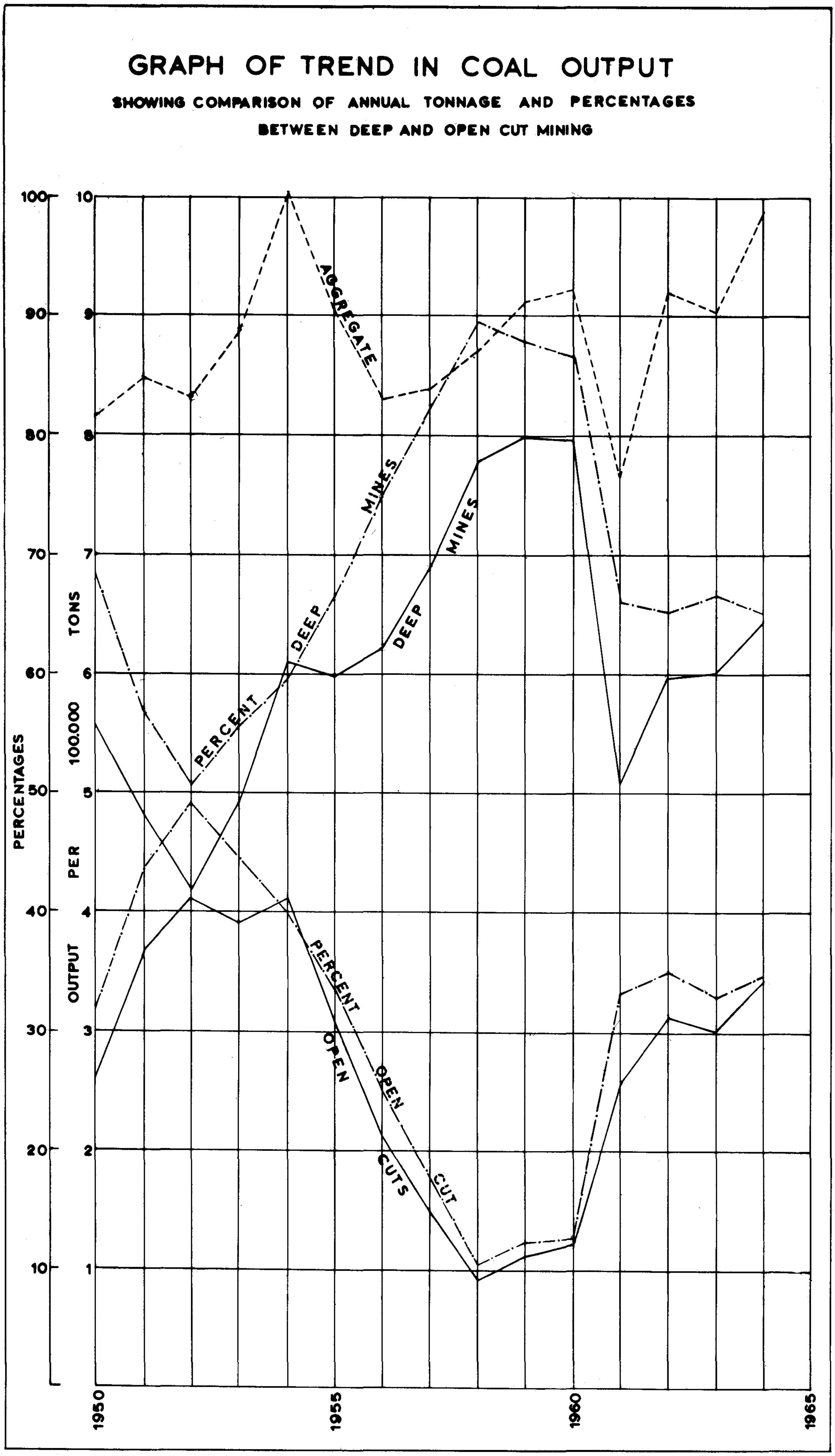
Goldfield or Mineral Field District	Gold Mining Leases			Mineral Leases			Miner's Homestead Leases			Miscellaneous Leases		
	Applied for	Ap-proved	In Force	Applied for	Ap-proved	In Force	Applied for	Ap-proved	In Force	Applied for	Ap-proved	In Force
Ashburton	....	....	....	....	10	136	....	....	....	2,792	5	5
Black Range	12	12	74	....	....	....	....	....	....	....	....	....
Broad Arrow	180	80	241	....	....	....	....	....	....	....	....	5
Bulong	72	72	36	....	....	....	....	....	....	....	....	3
Collie .... }	....	....	....	2,319	....	18,709	....	....	....	....	....	....
Private Property .... }	....	....	....	....	....	820	....	....	....	....	....	....
Coolgardie	215	143	720	....	....	295	....	....	1,480	32	32	60
Cue	36	36	60	....	....	....	....	....	1,233	....	....	....
Day Dawn	24	24	462	....	....	....	....	....	20	....	....	....
Dundas	....	....	6,175	....	....	....	340	320	909	....	....	....
East Coolgardie	236	118	5,280	....	....	....	100	....	3,353	....	....	1,180
Gascoyne	12	....	48	24	24	80	....	....	....	....	....	....
Greenbushes	....	....	....	8,714	6,225	6,302	....	....	588	....	....	....
Kanowna	....	....	22	....	....	....	....	....	702	....	....	....
Kimberley	....	....	46	....	....	72	....	....	....	....	....	....
Kunanalling	48	24	47	....	....	48	....	....	520	....	....	....
Kurnalpi	48	48	144	....	....	....	....	....	....	....	....	....
Lawlers	148	52	444	....	....	....	....	....	1,110	....	....	43
Marble Bar	31	25	299	....	....	40	14	....	13	41	36	71
Meekatharra	60	72	168	12	....	36	....	....	2,166	....	....	1
Menzies	....	....	360	....	....	....	....	....	740	....	....	10
Mount Magnet	20	20	929	....	....	38	....	....	30	....	....	....
Mount Malcolm	....	....	214	....	....	....	....	....	1,270	....	....	....
Mount Margaret	....	....	42	....	....	....	....	....	58	....	....	....
Mount Morgans	24	24	81	....	....	....	....	....	....	....	....	....
Niagara	....	....	107	....	....	....	....	....	20	....	....	....
Northampton .... }	....	....	....	48	....	70	....	....	53	....	....	....
Private Property .... }	....	....	....	....	....	33	....	....	....	....	....	....
Nullagine	36	36	234	....	....	....	....	....	22	....	....	48
Peak Hill	....	....	42	....	24	441	....	....	300	....	....	5
Phillips River	....	....	21	....	....	246	....	....	1,425	....	....	....
South-West .... }	....	....	48	24	....	....	....	....	....	....	....	2
Private Property .... }	96	24	24	24	....	1,096	....	....	....	....	....	....
Ularring	58	58	178	....	....	....	....	....	20	....	....	....
West Kimberley	....	....	....	....	....	755	....	....	....	....	....	75
West Pilbara	....	....	56	100	....	132	....	....	11	....	....	146
Wiluna	....	24	24	....	....	....	....	....	3,876	....	....	11
Yalgoo	12	12	76	....	....	....	....	....	10	....	....	....
Yerilla	....	....	376	....	....	....	....	....	10	....	....	....
Yilgarn .... }	65	48	578	....	....	....	500	20	433	....	....	58
Private Property .... }	....	....	60	....	....	....	....	....	....	....	....	....
Outside Proclaimed .... }	....	....	....	....	....	....	....	....	....	....	....	....
Private Property .... }	....	....	....	....	....	....	....	....	....	....	....	....
Totals	1,433	952	17,716	11,265	6,283	29,349	954	340	30,169	2,865	73	1,723

GRAPH OF COAL OUTPUT

SHOWING QUANTITIES AND VALUES AS REPORTED TO MINES DEPT.



YEAR	VALUE £A	TONS
1935	318013	537188
1936	331565	565075
1937	340444	553510
1938	375083	604793
1939	362811	557535
1940	364500	539427
1941	389278	556574
1942	461495	581176
1943	489721	531546
1944	583075	558322
1945	572896	543363
1946	730104	642287
1947	840249	730506
1948	880236	732938
1949	972245	750594
1950	1,287,749	814351
1951	1,716,788	848475
1952	2,457,296	830461
1953	3,073,073	886182
1954	3,588,818	1,018,343
1955	3,132,074	903,792
1956	2,797,506	830008
1957	2,552,655	838660
1958	2,280,649	870882
1959	2,356,534	917434
1960	2,439,195	922393
1961	1,680,259	765,740
1962	1,980,778	919,112
1963	1985,060	902,495
1964		
1965		
1966		
1967		



GRAPH OF TREND IN COAL OUTPUT
SHOWING COMPARISON OF ANNUAL TONNAGE AND PERCENTAGES
BETWEEN DEEP AND OPEN CUT MINING
PERCENTAGES
OUTPUT PER 100,000 TONS
AGGREGATE
PERCENT DEEP MINES
DEEP MINES
PERCENT OPEN CUT
OPEN CUTS
100
90
80
70
60
50
40
30
20
10
1950
1955
1960
1965

Total Area of Claims and Authorised Holdings Applied for, Granted and in Force as at 31st December, 1964

Goldfield or Mineral Field District	Gold other than Leases			Mineral other than Leases			For other Purposes			Miner's Rights Issued
	Applied for	Granted	In Force	Applied for	Granted	In Force	Applied for	Granted	In Force	
Ashburton	72	72	72	26	596	4,389	....	....	26	18
Black Range	84	84	84	....	....	24	....	....	1	10
Broad Arrow	1,298	1,271	1,003	....	....	....	....	....	11	8
Bulong	144	120	84	24	24	123	....	....	....	....
Collie	48	48	48	....	....	....	....	....	....	9
Private Property	....	....	....	....	....	....	....	....	....	....
Coolgardie	1,978	1,899	1,624	319	634	1,482	6	....	27	186
Cue	194	164	140	54	64	166	1	1	1	71
Day Dawn	72	72	72	....	....	....	....	....	20	....
Dundas	288	278	216	136	1,676	2,000	....	....	19	77
East Coolgardie	664	599	524	24	24	48	73	73	239	697
Gascoyne	....	24	24	189	723	911	....	....	5	51
Greenbushes	....	....	....	....	....	485	....	....	74	21
Kanowna	166	178	130	....	....	....	....	....	8	....
Kimberley	16	....	....	....	1,478	2,038	....	....	....	31
Kunanalling	282	282	246	....	....	....	....	....	25	....
Kurnalpi	36	36	36	....	24	....	....	....	....	....
Lawlers	283	259	231	13	13	55	....	....	12	....
Marble Bar	274	242	230	34,142	15,321	36,603	....	1	709	200
Meekatharra	180	180	180	48	204	234	....	....	10	99
Menzies	312	256	259	....	....	....	3	3	22	30
Mount Magnet	411	359	301	....	....	....	....	....	38	114
Mount Malcolm	367	343	247	....	....	....	1	....	194	128
Mount Margaret	82	82	82	....	....	....	....	....	4	....
Mount Morgans	102	102	82	48	48	77	....	....	1	....
Niagara	60	60	36	....	....	....	....	....	4	....
Northampton	....	....	....	62	84	620	1	1	1	23
Private Property	....	....	....	....	....	10	....	....	....	....
Nullagine	102	78	426	1,122	3,599	6,242	6	1	61	21
Peak Hill	47	37	47	96	96	1,095	3	3	14	....
Phillips River	24	24	....	40	323	4,086	....	....	9	40
Private Property	....	....	....	....	....	724	....	....	....	....
South-West	96	24	24	3,710	539	18,526	1	....	7	755
Private Property	192	24	24	2,411	295	16,680	....	....	....	....
Ularring	24	....	....	....	....	....	....	....	13	....
West Kimberley	....	....	....	....	....	48	....	....	53	8
West Pilbara	24	....	24	2,533	93	26,064	....	....	75	....
Wiluna	24	24	24	24	24	24	....	....	1,336	....
Yalgoo	36	36	36	527	483	1,068	25	20	33	7
Yerilla	96	120	36	....	....	....	....	....	12	6
Yilgarn	468	422	380	24	24	3,475	....	....	25	148
Private Property	....	....	....	....	....	....	....	....	....	....
Outside Proclaimed	....	....	....	20	....	720	....	....	....	....
Private Property	....	....	....	....	....	....	....	....	....	....
Totals	8,546	7,799	6,972	45,592	26,389	128,017	120	103	3,089	2,758

Claims and Authorised Holdings in Force on the 31st December, 1964

Goldfield or Mineral Field District	P.A.'s		D.C.'s		M.C.'s		R.A.'s		B.A.'s		M.A.'s		T.A.'s		G.A.'s		W.R.'s		Qu. Area	
	Number	Area	Number	Area	Number	Area	Number	Area	Number	Area	Number	Area	Number	Area	Number	Area	Number	Area	Number	Area
Ashburton	4	76	4	112	26	4,273	....	....	....	....	....	....	....	....	....	....	5	26	....	....
Black Range	4	84	....	....	1	24	4	1	....	....	....	....	....	....	....	....	....	....	....	....
Broad Arrow	59	1,003	....	....	....	....	1	1	1	1	....	....	....	....	....	....	4	9	....	....
Bulong	5	84	....	....	2	123	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Collie .... }	2	48	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Private Property .... }	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Coolgardie	94	1,756	....	....	13	1,350	3	1	....	....	1	1	....	....	3	8	5	17	....	....
Cue	14	170	....	....	10	136	4	1	....	....	....	....	....	....	....	....	....	....	....	....
Day Dawn	3	72	....	....	....	....	....	....	....	....	....	....	....	....	4	20	....	....	....	....
Dundas	13	222	....	....	33	1,994	....	....	....	....	....	....	1	5	1	2	2	12	....	....
East Coolgardie	38	548	....	....	1	24	32	8	....	....	2	4	12	56	4	17	13	39	7	115
Gascoyne	4	82	....	....	8	853	....	....	....	....	1	5	....	....	....	....	....	....	....	....
Greenbushes	....	....	....	....	10	485	1	1	....	....	....	....	....	....	10	42	2	31	....	....
Kanowna	9	130	....	....	....	....	....	....	....	....	....	....	....	....	2	7	1	1	....	....
Kimberley	....	....	....	....	11	2,038	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Kunanalling	12	246	....	....	....	....	....	....	....	....	....	....	....	....	....	....	3	25	....	....
Kurnalpi	3	36	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Lawlers	11	244	....	....	3	42	....	....	....	....	2	6	1	5	....	....	1	1	....	....
Marble Bar	34	706	218	20,036	196	16,091	2	1	6	6	7	21	2	10	3	3	23	668	....	....
Meekatharra	12	228	....	....	2	186	....	....	....	....	....	....	....	....	1	5	2	5	....	....
Menzies	18	259	....	....	....	....	....	....	....	....	1	1	....	....	3	8	6	13	....	....
Mount Magnet	19	301	....	....	....	....	1	1	....	....	....	....	....	....	17	32	4	5	....	....
Mount Malcolm	13	247	....	....	....	....	....	....	....	....	....	....	....	....	7	29	10	165	....	....
Mount Margaret	4	82	....	....	....	....	....	....	....	....	....	....	....	....	....	....	4	4	....	....
Mount Morgans	7	130	....	....	1	29	....	....	....	....	....	....	....	....	....	....	1	1	....	....
Niagara	2	36	....	....	....	....	....	....	....	....	....	....	....	....	....	....	2	4	....	....
Northampton .... }	2	34	....	....	9	586	....	....	....	....	....	....	....	....	....	....	1	1	....	....
Private Property .... }	....	....	....	....	1	10	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Nullagine	24	456	1	300	232	5,912	....	....	....	....	2	2	3	4	4	7	15	48	....	....
Peak Hill	8	143	....	....	28	999	1	1	....	....	2	8	1	5	....	....	....	....	....	....
Phillips River .... }	....	....	....	....	44	4,086	....	....	....	....	1	2	1	2	....	....	....	....	1	5
Private Property .... }	....	....	....	....	4	724	....	....	....	....	....	....	....	....	....	....	....	....	....	....
South-West .... }	1	24	10	1,967	154	16,559	....	....	....	....	....	....	....	....	....	....	1	7	....	....
Private Property .... }	3	72	4	341	105	16,291	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Ularring	....	....	....	....	....	....	....	....	....	....	1	1	2	4	....	....	7	8	....	....
West Kimberley	....	....	....	....	1	48	....	....	....	....	2	10	....	....	1	5	1	12	2	26
West Pilbara	9	216	....	....	156	25,872	4	2	12	12	....	....	....	....	4	19	8	42	....	....
Wiluna	2	48	....	....	....	....	....	....	....	....	2	3	1	3	1	5	5	1,325	....	....
Yalgoo	9	196	....	....	8	908	....	....	6	2	2	8	1	5	....	....	3	18	....	....
Yerilla	3	36	....	....	....	....	....	....	....	....	....	....	....	....	....	....	5	12	....	....
Yilgarn .... }	24	404	....	....	34	3,451	18	5	2	1	2	5	....	....	6	14	....	....	....	....
Private Property .... }	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Outside Proclaimed .... }	....	....	....	....	3	720	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Private Property .... }	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Totals	469	8,419	237	22,756	1,096	103,814	71	23	27	22	28	77	25	99	71	232	134	2,499	10	146

Alluvial Claims—None in Force. Miner's Rights issued—2,758

Number and Area of all Leases in Force on 31st December, 1964

Goldfield or Mineral Field District	Gold Mining Leases		Mineral Leases		Miner's Homestead Leases		Miscellaneous Leases	
	Number	Area	Number	Area	Number	Area	Number	Area
Ashburton	....	....	7	136	....	....	1	5
Black Range	7	74	....	....	....	....	....	....
Broad Arrow	16	241	....	....	....	....	1	5
Bulong	2	36	....	....	....	....	1	3
Collie .... }	....	....	63	18,709	....	....	....	....
Private Property .... }	....	....	3	820	....	....	....	....
Coolgardie	40	720	14	295	21	1,840	6	60
Cue	4	60	....	....	6	1,233	....	....
Day Dawn	23	462	....	....	1	20	....	....
Dundas	281	6,175	....	....	19	909	....	....
East Coolgardie	298	5,280	....	....	67	3,353	67	1,180
Gascoyne	2	48	3	80	....	....	....	....
Greenbushes	....	....	38	6,302	11	588	....	....
Kanowna	2	22	....	....	12	702	....	....
Kimberley	4	46	2	72	....	....	....	....
Kunanalling	2	47	1	48	2	520	....	....
Kurnalpi	6	144	....	....	....	....	....	....
Lawlers	24	444	....	....	5	1,110	4	43
Marble Bar	27	299	2	40	2	13	6	71
Meekatharra	10	168	3	36	12	2,166	1	1
Menzies	22	360	....	....	7	740	1	10
Mount Magnet	58	929	4	38	2	30	....	....
Mount Malcolm	12	214	....	....	9	1,270	....	....
Mount Margaret	2	42	....	....	7	58	....	....
Mount Morgans	4	81	....	....	....	....	....	....
Niagara	6	107	....	....	1	20	....	....
Northampton .... }	....	....	4	70	1	53	....	....
Private Property .... }	....	....	2	33	....	....	....	....
Nullagine	14	234	....	....	2	22	2	48
Peak Hill	3	42	14	441	6	300	1	5
Phillips River	2	21	11	246	107	14,245	....	....
South-West .... }	2	48	....	....	....	....	1	2
Private Property .... }	1	24	28	1,096	....	....	....	....
Ularring	12	178	....	....	1	20	....	....
West Kimberley	....	....	23	755	....	....	5	75
West Pilbara	3	56	10	132	2	11	8	146
Wiluna	1	24	....	....	17	3,876	3	11
Yalgoo	5	76	....	....	1	10	....	....
Yerilla	19	376	....	....	1	10	....	....
Yilgarn .... }	35	578	....	....	24	433	10	58
Private Property .... }	4	60	....	....	....	....	....	....
Outside Proclaimed .... }	....	....	....	....	....	....	....	....
Private Property .... }	....	....	....	....	....	....	....	....
Totals	953	17,716	232	29,349	346	33,552	118	1,723

	Acres
Gold Mining Leases on Crown Land	945–16,812
Gold Mining Leases on Private Property	8– 904
Miner's Homestead Leases on Crown Land	346–33,552
Miner's Homestead Leases on Private Property	*Nil*
Mineral Leases on Crown Land	199–27,400
Mineral Leases on Private Property	33–1,949
Other Leases on Crown Land	118–1,723

PART IV—MEN EMPLOYED

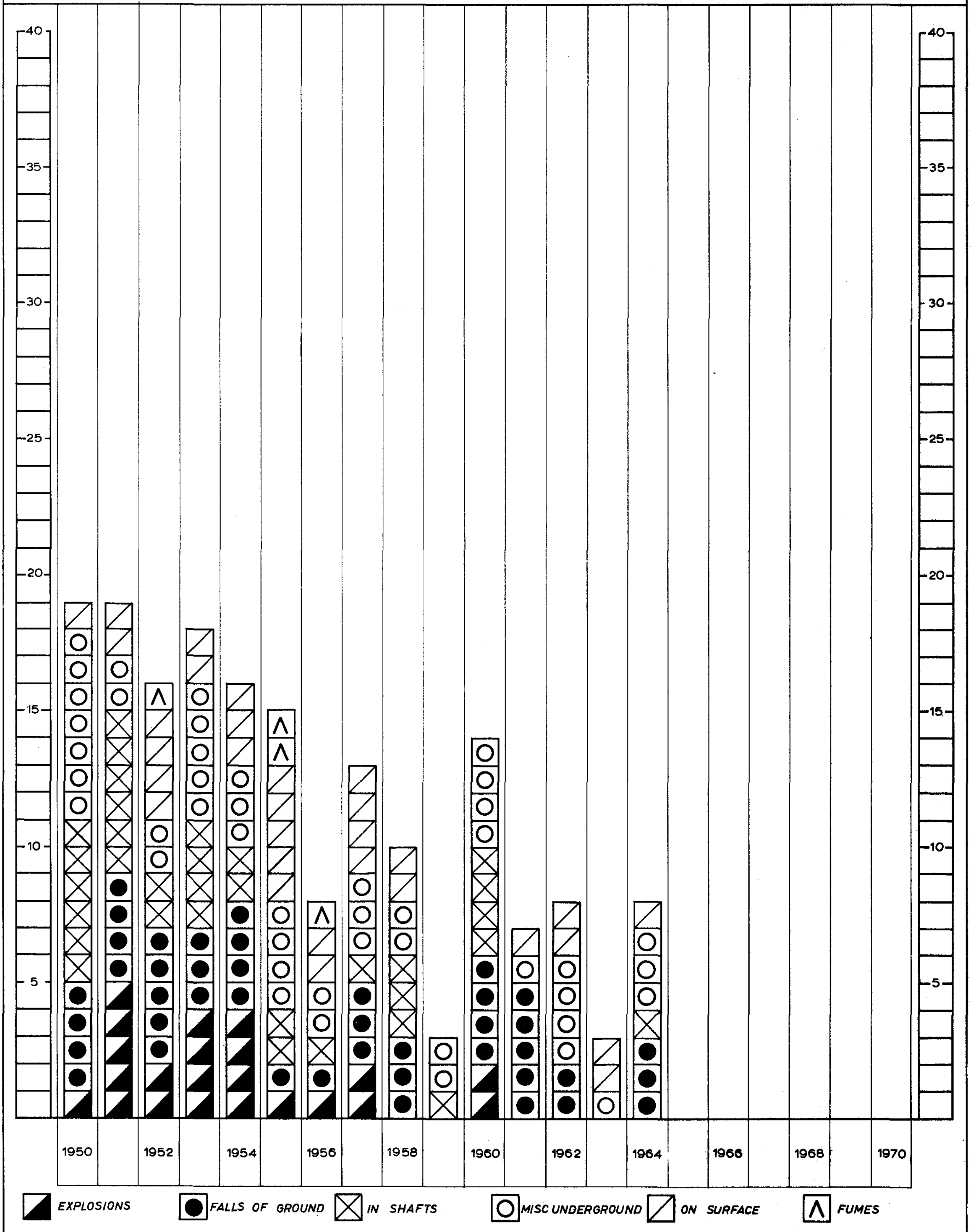
TABLE 7

Average number of Men reported as engaged in Mining during 1963 *and* 1964

Goldfield	District	Total 1963	Total 1964
Kimberley	....	....	....
West Kimberley	....	....	....
Pilbara	Marble Bar	26	30
	Nullagine	18	18
West Pilbara	....	1	1
Ashburton	....	....	....
Gascoyne	....	....	1
Peak Hill	....	4	2
East Murchison	Lawlers	19	25
	Wiluna	3	5
	Black Range	4	4
Murchison	Cue	31	33
	Meekatharra	12	10
	Day Dawn	12	16
	Mt. Magnet	250	247
Yalgoo	....	1	....
Mt. Margaret	Mt. Morgans	2	3
	Mt. Malcolm	231	25
	Mt. Margaret	2	3
North Coolgardie	Menzies	103	101
	Ularring	37	31
	Niagara	5	5
	Yerilla	23	19
Broad Arrow	....	97	88
North-East Coolgardie	Kanowna	28	19
	Kurnalpi	17	13
East Coolgardie	East Coolgardie	3,179	3,047
	Bulong	10	10
Coolgardie	Coolgardie	166	107
	Kunanalling	20	19
Yilgarn	....	231	157
Dundas	....	369	344
Phillips River	....	....	....
South-West Mineral Field	....	....	....
Total, Gold Mining	....	4,901	4,383
Minerals Other than Gold—			
Asbestos		351	370
Barytes		1	1
Bauxite		7	273
Beryl		35	12
Building Stone		2	7
Clays		15	16
Coal		757	765
Copper		117	73
Cupreous Ore (Fertiliser)		72	54
Felspar		5	6
Glass Sand		3	3
Gypsum		20	16
Iron Ore		417	448
Lead		2	21
Limestone		16	18
Magnesite		1	....
Manganese		28	74
Mineral Beach Sands (Ilmenite, etc.)		213	262
Pyrites		99	99
Spodumene		2	....
Talc		3	4
Tanto/Columbite		8	9
Tin		117	104
Total, Other Minerals		2,291	2,635

DIAGRAM OF ACCIDENTS

SHOWING THE NUMBER OF DEATHS IN THE MINES AND QUARRIES OF WESTERN AUSTRALIA



PART V—ACCIDENTS

TABLE 8

Men employed in mines, killed and injured in mining accidents during 1963-64
A. According to Locality of accident.

Goldfield	Killed		Injured		Total Killed and Injured	
	1963	**1964**	1963	**1964**	1963	**1964**
1. Kimberley	....	**1**	....	....	....	**1**
2. West Kimberley	....	....	2	**8**	2	**8**
3. Pilbara	....	....	1	**3**	1	**3**
4. West Pilbara	....	....	12	**16**	12	**16**
5. Ashburton	....	....	4	**11**	4	**11**
6. Gascoyne	....	....	4	....	4	....
7. Peak Hill	....	....	....	....	....	....
8. East Murchison	....	....	....	....	....	....
9. Murchison	....	**1**	18	**23**	18	**24**
10. Yalgoo	....	....	....	....	....	....
11. Mount Margaret	....	....	27	**1**	27	**1**
12. North Coolgardie	....	....	6	**6**	6	**6**
13. North-East Coolgardie	....	....	....	....	....	....
14. Broad Arrow	....	....	....	....	....	....
15. East Coolgardie	1	**5**	245	**231**	246	**236**
16. Coolgardie	....	....	4	....	4	....
17. Yilgarn	....	....	10	....	10	....
18. Dundas	....	....	33	**33**	33	**33**
19. Phillips River	1	**1**	11	**6**	12	**7**
Mining Districts—						
Northampton	....	....	....	**2**	....	**2**
Greenbushes	....	....	....	....	....	....
Collie	....	....	56	**55**	56	**55**
South-West	1	....	12	**37**	13	**37**
Total	3	**8**	445	**432**	448	**440**

B.—*According to Causes of Accidents*

	1963		**1964**		Comparison with 1963	
	Fatal	Serious	Fatal	Serious	Fatal	Serious
1. Explosives	....	**5**	....	**8**	....	+ 3
2. Falls of Ground	....	**30**	3	**25**	+ 3	— 5
3. In Shafts	....	**8**	1	**8**	+ 1	....
4. Miscellaneous Underground	1	**281**	3	**273**	+ 2	— 8
5. Surface	2	**121**	1	**117**	— 1	— 4
6. Fumes	....	....	....	**1**	....	+ 1
Total	3	**445**	8	**432**	+ 5	— 13

PART VI—STATE AID TO MINING.

(a) State Batteries.

At the end of the year there were 20 State Batteries including the Northampton Base Metal Plant.

From inception to the end of 1964, gold, tin, tungsten, lead, copper and tantalite ores to the value of £18,808,355 have been treated at the State Batteries. Included in the above amount is gold premium of £7,220,360 and premium paid by sales of gold by the Gold Producers' Association Ltd., of £43,480. £18,312,691 came from 3,461,354¾ tons of gold ore, £94,913 from 81,904¼ tons of tin ore, £18,850 from 3,960 tons tungsten ore, £362,985 from 31,620¾ tons lead ore, £5,966 from 220½ tons of copper ore and £12,950 from 203¼ tons of tantalite ore.

During the year 43,966¾ tons of gold ores were crushed for 14,774 ozs. bullion, estimated to contain 12,521 ozs. fine gold, equal to 5 dwts. 17 grs. per ton. The average value of sands after amalgamation was 2 dwts. 23 grs. per ton, making the average head value 8 dwts. 16 grs. per ton. Cyanide plants produced 2,600 ozs. fine gold, giving a total estimated production for the year of 15,121 ozs. fine gold valued at £236,646.

The working expenditure for the year for all plants was £220,564 and the revenue was £39,993 giving a working loss of £180,571 which does not include depreciation or interest. Since the inception of State Batteries, the Capital expenditure has been £837,305 made up of £657,693 from General Loan Funds; £137,204 from Consolidated Revenue; £28,622 from Assistance to Gold Mining Industry; and £13,786 from Assistance to Metalliferous Mining.

Head Office expenditure including Workers' Compensation Insurance and Pay Roll Tax was £28,662 compared with £22,687 for 1963.

The working expenditure from inception to the end of 1964 exceeds revenue by £2,057,821.

(b) Prospecting Scheme.

The number of men approved for assistance under the prospecting scheme during the year ended 31st December, 1964, was 46, decrease of 8 compared with last year. There were 48 cancellations during the year and after allowing for 5 men under suspension on 31st December, 1964, there were 41 men still in receipt of assistance.

The total cost of maintaining the scheme for the year was £10,316 12s. 4d., and refunds amounted to £1,624 8s. 8d.

During the year crushings reported totalled 1,735 tons 5 cwt. for a return of 774 ozs. 6 dwts. of gold.

Progressive total figures since the inception of the scheme are as follows:

Expenditure	£450,187 1 2
Refunds	£88,849 9 11
Ore Crushed	118,853 tons
Return	55,124 ozs. 3 dwts.

The above figure for expenditure includes £80,346 1s. 9d. subsidised by the Commonwealth Government.

(c) Geological Survey of Western Australia.

All the work of the Geological Survey is directed towards assistance to Mining, Industry and Agriculture, although the direct effect of the work may, in some instances be difficult to observe. Of the more direct aid projects, the following are noteworthy:

A comprehensive survey of the blue asbestos resources of the Hamersley Range was commenced during the year to assist the asbestos industry and Australian Blue Asbestos Pty. Ltd., who are currently engaged in a protracted drilling programme to establish ore reserves in the Wittenoom Gorge area. This survey is a major project and is expected to be continued for the next two years.

Manganese deposits at Woodie Woodie and Mt. Sydney were diamond drilled and examined by geophysical methods to determine the extent of the deposits in depth. The vermiculite deposit at Young River was re-examined in an attempt to renew interest in this prospect. The Comet Gold Mine at Pinnacles near Cue was assisted by examination and mapping of a newly opened level, while at Lake Grace a gold prospect was sampled and reported on for the owner.

Industrial rocks and minerals were again in demand in the Perth area and most enquiries for them were satisfied. An initial examination of deposits of glass sand near Gnangara Lake was made, and advice and information given to a number of companies seeking such materials as moulding sands, limestone, aggregate, gravel, clays and shales.

Systematic regional geological mapping continued in the Kimberley, Ashburton, Kalgoorlie and Bunbury areas of the State. Exploration companies were provided with basic geological data to assist their search for ore deposits.

Engineering geology services were provided to assist such important developmental projects as the Standard Gauge Railway, Ord River Development, and surface water conservation in a number of places in the State.

Underground water investigations were undertaken at widely scattered localities throughout the State to assist Government Departments, local authorities, and private individuals to better develop their natural resources. In most cases sufficient water was found to meet the requirements or valuable geological information was obtained to guide future search.

By critical review of company oil search programmes, officers of the Survey attempted to stimulate the search for oil in Western Australia. During the year oil and gas were found at Yardarino and Barrow Island and the tempo of exploration quickened.

A more comprehensive summary of the activities of the Survey is given under "Operations" in Division IV of this report, and under "Reports" are given written accounts of some of the projects.

In addition to work in the field, officers of the Survey have rendered considerable assistance by way of information and services to individuals and companies who are more than ever regarding the Geological Survey as a starting point for any mineral search.

PART VII—SCHOOL OF MINES.

(a) *Kalgoorlie.*

The number of students enrolled in 1964 was 329 a decrease of 36 by comparison with 1963. Although the total number of students enrolled decreased, the number enrolled for Associateship Courses increased slightly. This tendency will probably continue and the proportion of students enrolled for Associateship or Certificate Courses appears likely to continue to increase.

On the 4th December 1964 Mr. S. Edelman, Senior Lecturer, retired after a period of 30 academic years at the School. Mr. Edelman was well regarded by past and present students and also by members of the school staff.

Two other lecturers, Messrs. Wallis and Lewis, resigned to take up positions in Perth.

Only very minor changes were made to the Courses, which remained very much as they were in 1963. The Associateship Courses were re-arranged to provide for two years' full time study followed by two years' part time study for each Course. It was felt that whenever possible some full time study should be done by all Associateship Course students. This would enable students to devote more time to study and would also reduce the time taken to complete the Course. Notwithstanding this arrangement the Course can still be completed by all part time study.

Two students held Mines Department Scholarships. One student who held an Entrance Scholarship was enrolled for the "Q" subjects and completed a satisfactory year's work. The other student, who held a Senior Scholarship, elected at the end of the year to continue as a part time student and to resign his Scholarship.

Twelve students held Chamber of Mines Scholarships and all completed a satisfactory year's work. Three students completed the Courses for which they enrolled, and in all 18 students have now completed Courses as Chamber of Mines Scholarship holders.

The usual awards were made at the end of the year and are listed in Appendix 2 of the Director's Report.

Mr. B. J. Fraser, who held a Chamber of Mines Scholarship was awarded an A.E.I. Overseas Fellowship at the end of the year and will leave for England early in 1965, in which year there will be three students in England who have held or are holding A.E.I. Overseas Fellowships—G. A. Buckett, W. E. Baldwin and B. J. Fraser.

During the year 20 Associateship Diplomas and 23 Certificates were granted, and 4 Technician Courses were completed. These numbers are higher than those of recent years, but include some Diplomas and Certificates completed in the previous year for which immediate application had not been made.

At a function held in the evening of the 27th May, 1964, held in the Boulder Town Hall, Diplomas, Certificates and Prizes were presented by the Minister for Mines, the Hon. A. F. Griffith.

Progress in the Library became possible again this year with the appointment of Miss M. Hartigan, a graduate of the University of Western Australia and a qualified librarian. The School Library now contains 9,030 catalogued items and 871 were added during the year.

The School continued to provide the usual services to the public in addition to its teaching activities. The number of samples submitted for assay and/or determination was 419. These do not include those submitted to Metallurgical Laboratory for pay assays or other work, but are those samples examined without cost for prospectors.

The new buildings for the Department of Mathematics and Physics were completed in time for the opening of the School in 1964 and very greatly improved conditions in that Department. Preparation of plans for the new Mining and Engineering buildings continued during the year and it is expected that the first stage of these buildings will be completed in February, 1966.

The Advisory Committee met on seven occasions. Mr. Havlin resigned from the Committee in May and Mr. Lithgow was appointed to replace him. Equipment to the value of £906 was approved for purchase during the year.

Seven reports of investigations and 406 Certificates were issued by Kalgoorlie Metallurgical Laboratory during the year. The Senior Research Metallurist continued as a member of the Chamber of Mines Metallurgical Committee. Many enquiries for metallurgical information were answered by the Laboratory staff.

The Students' Association was active during the year and the usual functions were held. The Ball was well attended and a donation of £202 was made to the Special Education Centre in Boulder. The Association's hockey team won the Eastern Goldfields "A" Grade competition.

(b) Norseman.

The number of students enrolled was 59, a decrease of 9 by comparison with the previous year.

Cadet Rasmussen completed his cadetship at the School and left the district at the end of the year.

The examination results at Norseman were very good.

The Reg. Dowson Scholarships for 1964 were awarded to K. A. Sweet and to D. A. Perkin. Of the two students awarded Reg. Dowson Scholarships in 1963 one completed a fair year's work and the other a good year's work. No other awards were made to Norseman students.

Very little was done to the buildings, but these are in a satisfactory condition.

PART VIII—INSPECTION OF MACHINERY.

The Chief Inspector of Machinery reports that the number of useful boilers registered at the end of the year totalled 8,735 against 8,297 for the preceding year, showing an increase of 438 boilers under all adjustments.

Of the 8,735 useful boilers 2,497 were out of use at the end of the year, 5,138 thorough and 908 working inspections were made, and 5,159 certificates were issued.

Permanent condemnations total 42 and temporary condemnations 5; 106 boilers were transferred beyond the jurisdiction of the Act.

The total number of machinery groups registered was 50,370 against 48,012 for the previous year, showing an increase of 2,258.

Inspections made total 32,136 and 6,633 certificates were granted.

The total miles travelled for the year were 123,471 against 125,961 miles for the previous year, showing a decrease of 2,490. The average miles travelled per inspection were 3.23 as against 3.15 miles per inspection for the previous year.

530 applications were received and dealt with for Engine Drivers and Boiler Attendants' Certificates, and 484 certificates all classes were granted as follows:—

Winding Competency (including certificates issued under Regulation 40 and Section 60)	12
First Class Competency (including certificates issued under Regulations 40 and 45, and Sections 60 and 63)	21
Second Class Competency (including certificates issued under Regulation 40 and Section 60 of the Act)	15
Third Class Competency (including certificates issued under Regulation 40 and 45 and Sections 60 and 63)	14
Locomotive and Traction Competency (including certificates issued under Regulation 40 and Section 60)	1
Diesel Locomotive "B" Class Certificates of Competency (including certificates issued under Regulation 40 and Sections 53 and 56)	7
Internal Combustion Competency (including certificates issued under Regulation 40 and Section 60)	32
Crane and Hoist Competency (including certificates issued under Regulation 40 and Section 60)	278
Boiler Attendant's Competency (including certificates issued under Regulation 40 and Section 60)	90
Copies	13
	483

The total revenue from all sources during the year was £17,051 16s. 8d. as against £17,126 18s. 11d. in the previous year, showing a decrease of £407 8s. 4d.

Total expenditure for the year was £51,667 10s. 5d. against £50,266 19s. 6d. the previous year, showing an increase of £1,400 10s. 11d.

PART IX—GOVERNMENT CHEMICAL LABORATORIES.

The main administrative change during the year 1964 was the filling of the position of Deputy Director, by the promotion of Mr. R. C. Gorman formerly Divisional Chief of the Agriculture and Water Supply Division.

During the year two of our laboratories which had been unusable because of building operations, became operational again, but as yet the full number of professional staff which can now be accomodated has not been obtained.

The close association of the Government Chemical Laboratories with other Government Departments and with kindred associations was maintained during 1964 and various members of the staff are members of 12 committees connected with the activities of these organisations. In addition Mr. Donnelly has been appointed to the recently constituted National Coal Research Advisory Committee.

Some major items of equipment were added in 1964 including a Gelman sequential sampler and accessories for air pollution studies; a spiral separator for mineral purification; a commercial atomic absorption spectrograph and a large camera for X-ray powder diffraction.

The total number of registrations in 1964 was 3,551 almost the same as for 1963 (3,532) and the number of samples received was 12,962 an increase of nearly 15% over the number received in 1963. Samples were received from 20 of the 28 Government Departments shown in the Public Service List for 1964, a marked increase over the 15-16 in past years.

Samples received were allocated to the various Divisions of the Laboratories according to the specialised work undertaken by each Division. In some cases samples were allocated to more than one Division to ensure a full elucidation of the problem.

Fees were charged for work undertaken for some State Government Departments, Government Instrumentalities, for Commonwealth Government Departments, Hospitals, Milk Board, private firms and the general public, but the greater part of the work of the Laboratories is done free for other Government Departments, together with an appreciable amount of free mineral identification and assay to assist prospectors.

Agriculture and Water Supply Division.

In 1964 there was an increase of 33% in the number of samples received compared with the previous year. This increase was mainly due to very large increases in the number of clover, pastures, wheat and soil samples received, primarily from Department of Agriculture experiments on the use of copper, phosphate and nitrogenous fertilisers.

Another aspect of the Division's work that has been gradually increasing and assumed greater importance in 1964 is in the field of water treatment. Visits were made to water treatment plants at Northampton, Kulin, Lake Grace, Donnybrook, Eaton and Capel.

Two delegates attended the Third Australian Plant Nutrition Conference held at the University and a considerable amount of useful information was obtained and valuable contacts made with workers in similar fields in C.S.I.R.O. and other Government Departments.

The first stage of the building extensions was occupied this year, and it is hoped that the second stage of laboratory extensions will be completed early in 1965.

Engineering Chemistry Division.

In discharging its functions of carrying out research into the development and utilisation of the natural resources of the State, some original research and development projects were undertaken by the Division during the year. Of these, work on the process for upgrading local ilmenite, was finalised; work on the utilisation of iron oxide by-product from the above process was continued from last year; investigations into utilisation of titaniferous magnetite deposits, containing vanadium, were initiated during the year.

A larger proportion of time was, however, spent on a number of sponsored projects undertaken as bench and pilot plant scale investigations, at the request of private interests. In addition, on a number of occasions, free oral advice has been given to other Government Departments and to industrial undertakings.

Food, Drugs, Toxicology and Industrial Hygiene.

As in previous years the greater proportion of the work of this Division in 1964 again consisted of chemical examinations for the Departments of Agriculture, Police and Public Health, as well as for the Milk Board of Western Australia and the Swan River Conservation Board, but the normal variety of miscellaneous work was also performed for other Departments and for the general public. As in 1963 there was a sharp increase in the number of samples received under the classification of Public Pay, chiefly in connection with the medical diagnosis of industrial toxicology.

The staff of the Division was again short of one professional officer throughout the year. As a consequence of the shortage of qualified staff, three technicians (in course of qualifying) were appointed during the latter part of the year, and it is expected that early in 1965 the staff of the Division will number fifteen officers, of which eleven will be qualified chemists.

Accomodation was somewhat relieved by the completion of a new "Trace Laboratory' 'which is double the floor space of the previous room and provides working space for four officers.

Fuel Technology Division.

There were 206 registrations of investigations and samples allocated to the Fuel Technology Division during 1964. They related to analyses of coal and other fuels and gasses, air pollution, light weight aggregates, the conductivity of insulating materials, dust arrestment, size analysis of dust and to works investigations.

They have ranged from an investigation of drying and firing conditions on a tunnel kiln making house bricks to the determination of the food calorie value of a diabetic soft drink. An investigation of considerable community interest has been into the sources, intensity and objectionable character of odours from Subiaco Sewerage Treatment Plant for which measures of alleviation were suggested and some of these have been implemented.

Industrial Chemistry Division.

As in previous years the work may be classified as routine; Consultative Practice; Development Research (including investigational).

There were sixty-five samples submitted under the classification of routine work. In contrast to last year no cement additives were examined, but two samples of set-concrete were analysed to find if cement additives had been included in the mix.

The Advisory Service was called upon to deal with a variety of queries. Quite a number dealt with questions on paints, plastics and building materials.

As in previous years investigational and research work was carried out for private industry.

Mineralogy, Mineral Technology and Geochemistry Division.

The number of samples examined during the year was 2,395 a decrease on the previous year's figure, which was a record number, but much the same as the average for the previous five years.

In addition to the Mines Department and its branches, thirteen Government Departments or instrumentalities submitted samples for examination.

At the end of the year the Mineral Division Collection contained 3,592 specimens representing an addition of 75 during the year.

The discovery of gold in the form of telluride in Assam, India led to a request from that country for specimens of telluride materials that could be used as standards for determinative work. The Division was able to supply the Director of Geology and Mining, Government of Assam, with the necessary specimens.

The testing of concrete aggregate continued as an important function of the Division. Work in this connection was carried out for the Public Works Department, Main Roads Department and the United States Navy as well as for a number of private contractors.

The usual mineral specimens were received and dealt with.

Physics and Pyrometry Section.

The work of this section was carried out under three headings—Pyrometry, Thermal Methods and X-ray Methods.

The section has co-operated with the various Divisions of the Laboratories.

Four National Association of Testing Authorities Certificates were issued during the year for the calibration of mercury in glass thermometers.

PART X—EXPLOSIVES.

There has been no change in the Head Office staff, and some difficulties are arising from expanding duties and distant inspectional work resulting from new industries, work and explosives traffic in the North. Increased staff will become essential when the Dangerous Goods control regulations are operative.

The staff position at Woodman's Point is satisfactory and accommodation for the staff at the Reserve has been improved.

Explosives importations have been made by sea and by rail. Two shipments of Du pont explosives were received from the United States of America.

Blasting agent grade amonium nitrate prill rose to a consumption of 2,500-3,000 tons during 1964. Supplies arrived from overseas in drums, supplemented by railage of 50 lb. and 80 lb. polythene packs.

The jetty at Woodman's Point was used for supplying geoseismic off-shore shooting boats, etc.

Intended works at Geraldton and heavy industry to the North brought many enquiries as to explosive storage. At Geraldton a 40 acre block has been gazetted recently as an Explosive Reserve, and steps are being taken to ensure adequate provision at Port Hedland. In view of the developments in the North West it has been recommended that in the siting of new mining towns and the development of present and of future ports, at least 50 acres of suitably isolated land be set aside for explosives reserves.

Several permits were issued both for professional displays of fireworks and communal "bonfire nights" at which supervision was exercised and fire hazard borne in mind. This type of celebration had much to commend it by comparison with the sometimes indiscriminate and uninhibited use of fireworks in back-yards.

PART XI—MINERS' PHTHISIS ACT AND MINE WORKERS' RELIEF ACT.

Under arrangements made with this Department, the State Public Health Department continued the periodical examination of mine workers. The work was carried on throughout the year at the State X-ray Laboratory, Kalgoorlie, and a mobile x-ray unit visited the North Coolgardie, Mt. Margaret, Murchison, Peak Hill, Pilbara, West Pilbara, Dundas, Yilgarn and Phillips River Goldfields and the Northampton and South West Mineral Fields.

The examinations under the Mine Workers' Relief Act during the year totalled 4,155 as compared with 5,498 for the previous year, a decrease of 1,343. Under the Mines Regulation Act 1,779 miners were examined, a decrease of 227 by comparison with 1963. These were in addition to the 4,155 examined under the Mine Workers' Relief Act. Of the 1,779 men examined under the Mines Regulation Act 1,524 were new applicants and 255 were re-examinees.

Compensation paid during the year amounted to £8,832 12s. 8d. compared with £9,597 1s. 8d. for the previous year.

The number of beneficiaries under the Act as on the 31st December 1964 was 77, being 6 ex-miners and 71 widows.

During the year the Mine Workers' Relief Act was amended to provide Section 56A benefits to service pensioners and to widows whose husband immediately prior to his death was qualified for such benefits save that he was receiving workers' compensation payments. Also the statuatory authority for the payment of compensation to diseased mine workers was removed from the Mine Workers' Relief Act and re-enacted in the Workers' Compensation Act. A number of other minor amendments were also made.

PART XII—CHIEF DRAFTSMAN.

The staff remained at the same number as last year but due to keen interest in the mineral potential and iron ore resources of the State there was an increase in the work required to be performed in all sections. The staff have responded very well and the branch has succeeded in coping with the added demand.

During the year 7 contract surveyors carried out field work for the Department throughout all of the active goldfields and mineral fields.

Diagrams in connection with these surveys were drawn and examined. Plans were also prepared on lease instruments and other documents.

Two hundred and three technical plans were prepared for the Geological Survey together with 5,609 prints and duplicates from various originals.

A total of 15,415 dyeline prints and duplicates were produced and work was continued on re-drawing the 20 chain lithographic series.

STAFF.

Once again activity in the mining industry continued unabated. Exploration of Western Australia's mineral potential has engaged the attention of a number of overseas companies and of local companies in the past year. This has increased the volume of work passing through the Department. Our officers have responded well to the increased activity and carried out their duties loyally and efficiently, and I would again take this opportunity of thanking them for their efforts.

In this Summary of the various activities of the Department, I have commented only on the principal items. Divisions II to XII of this publication contain the detailed reports of the responsible Branch officers.

(Sgd.) A. H. TELFER,
Under Secretary for Mines.

12th June, 1965.

DIVISION II

•

Report of the State Mining Engineer for the Year 1964

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Under Secretary for Mines:

I submit the Annual Report of the State Mining Engineer's branch which has been prepared by the Acting Assistant State Mining Engineer.

The gold production figures show a decrease in tonnage treated and gold produced and the average grade was lower.

The closure of two low grade producers—Sons of Gwalia and Great Western—might have been expected to produce a rise in the average grade. Most of the large producers have treated ore of lower grade than in the previous year. The only exception is the Central Norseman. The tonnages treated are somewhat similar and in view of the closure of three mines the total is satisfactory. Shortage of labour is a problem.

In view of all these circumstances the result is encouraging as regards the survival of the industry but the profit margin has been smaller.

The development of trackless mining at Mount Charlotte has been successful. Some difficulties have been experienced particularly with roof support but the general result has been satisfactory.

The output of Collie coal was slightly above that for the previous year. The position as regards development is satisfactory.

The output of open cut coal was 343,312.5 tons and the overburden removed was 1,253,040 cubic yards a ratio of 1 to 3.7.

The value of minerals other than gold shows an increase from £8.6 million in 1963 to £13.6 million in 1964. About £3.5 million of this increase is accounted for by the value of alumina produced at Kwinana. There have also been significant increases in the value of beach sands and of tin.

The establishment of a Chrysotile treatment plant at Marble Bar on a small scale indicates the possibility of producing this mineral on a wider scale.

A wide spread search for base metals has not resulted in any spectacular development but with increased prices small scale mining of lead and copper shows signs of a revival.

The development of the iron ore at Koolan Island is now complete and shipments will be made during 1965.

Operations in the Pilbara, at Koolyanooka, and at Koolyanobbing are passing from the exploratory to the developmental stage and production should commence within a comparatively short time.

The drilling section has conducted a versatile programme including the investigation of dam sites and harbour works as well as assisting private companies interested in drilling.

E. E. BRISBANE,
State Mining Engineer.

15th June, 1965.

State Mining Engineer:

Mining activities for the year 1964 are described in this report which is based on information supplied by the Statistician and Inspectors of Mines. The section on drilling, written by Inspector Haddow, and the report of the Board of Examiners for Mine Managers and Underground Supervisors' Certificates appear as appendices to this report.

STAFF.

In February, 1964, Assistant District Inspector of Mines (Ventilation) A. J. Murphy was made Special Inspector of Mines, Ventilation, and on 3rd December was appointed District Inspector of Mines, Ventilation.

Mr. R. J. George-Kennedy commenced duties as Assistant District Inspector of Mines, Ventilation on 13th April, 1964.

ACCIDENTS.

Fatal and serious accidents reported to the Department are shown below. The corresponding figures for 1963 are shown in brackets.

There were 8 (3) fatal and 432 (445) serious accidents.

In gold mines there were 6 (1) fatal and 290 (335) serious accidents. The number of men employed in such mines was 4,785 (5,297). The accident rate per 1,000 men was thus 1.25 (0.19) for fatal accidents and 60.60 (63.24) for serious accidents.

An oil drill crew man was killed when he fell from an oil drill rig.

A skipman was killed in the shaft of a copper mine.

A classification of serious accidents showing the nature of the injuries is given in Table "A".

TABLE A

Serious Accidents for 1964

Class of Accident	West Kimberley	Pilbara	West Pilbara	Ashburton	Murchison	Northampton	Mount Margaret	North Coolgardie	East Coolgardie	Dundas	Phillips River	South-West	Collie	Total
Major Injuries—exclusive of Fatal—														
Fractures—														
Head	....	....	1	....	....	....	....	....	....	....	....	....	....	1
Shoulder	....	....	....	....	....	....	....	....	6	....	....	....	....	6
Arm	....	....	1	....	....	....	....	....	1	1	1	....	....	4
Hand	....	1	....	....	....	....	....	1	....	....	....	1	....	3
Spine	....	....	....	....	....	....	....	....	4	....	....	....	1	5
Rib	....	....	....	....	....	....	....	....	1	....	1	1	4	7
Pelvis	2	....	....	....	....	....	....	....	1	....	....	....	1	4
Thigh	....	....	....	....	....	....	....	....	1	....	....	....	....	1
Leg	....	....	....	....	1	....	....	....	5	....	....	....	....	6
Ankle	....	....	....	....	1	1	....	....	1	....	....	....	....	3
Foot	....	....	1	....	....	....	....	....	....	1	....	....	....	2
Amputations—														
Arm	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Hand	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Finger	....	....	....	....	....	....	....	....	1	1	....	2	1	5
Leg	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Foot	....	....	....	....	....	....	....	....	1	....	....	....	....	1
Toe	....	....	....	....	....	....	....	....	2	....	....	....	....	2
Loss of Eye	....	....	....	....	....	....	....	....	1	....	....	....	....	1
Serious Internal	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Hernia	....	....	....	....	1	....	1	....	3	....	....	2	3	10
Dislocations	....	....	2	....	....	....	....	....	1	....	....	....	....	3
Other Major	2	1	2	....	1	....	....	....	2	....	....	1	2	11
Total Major	4	2	7	....	4	1	1	1	31	3	2	7	12	75
Minor Injuries—														
Fractures—														
Finger	1	....	....	....	1	....	....	....	4	....	1	6	2	15
Toe	....	....	1	....	1	....	....	....	5	1	....	1	....	9
Head	....	....	....	....	....	....	....	1	3	3	....	....	....	7
Eyes	....	....	....	....	1	....	....	....	8	1	....	1	1	12
Shoulder	....	....	....	....	....	....	....	....	4	....	....	1	1	6
Arm	....	....	....	....	....	....	....	1	12	2	....	3	2	20
Hand	....	....	1	3	6	....	....	....	52	14	....	4	3	83
Back	1	....	1	2	1	....	....	....	38	1	2	5	15	66
Rib	....	....	....	....	....	....	....	....	1	....	....	....	....	1
Leg	....	....	3	2	7	1	....	1	40	4	....	4	10	72
Foot	2	1	2	3	2	....	....	....	23	4	....	2	3	42
Other Minor	....	....	1	1	....	....	....	2	10	....	1	3	6	24
Total Minor	4	1	9	11	19	1	....	5	200	30	4	30	43	357
Grand Total	8	3	16	11	23	2	1	6	231	33	6	37	55	432

There were no serious accidents reported in the year under review in the following Goldfields :—

Kimberley, Peak Hill, Gascoyne, East Murchison, Yalgoo, Broad Arrow, North-East Coolgardie, Coolgardie, Yilgarn, Greenbushes.

Table "B" shows the fatal, serious and minor accidents reported and the number of men classified according to the mineral mined.

TABLE B

Accidents segregated according to mineral mined

Mineral	Men Employed	Accidents		
		Fatal	Serious	Minor
*Asbestos	370	....	15	63
Barytes	1	....	....	....
*Bauxite	273	....	11	45
Beryl	12	....	....	....
Building Stone	7	....	....	....
Clays	16	....	....	....
*Coal	765	....	55	237
*Copper	127	1	6	39
Felspar	6	....	....	....
Glass Sand	3	....	....	....
Gold	4,785	6	290	1,173
Gypsum	16	....	....	1
*Iron Ore	448	....	8	13
Lead	21	....	2	....
Limestone	81	....	1	....
Manganese	74	....	1	....
*Mineral Sands	262	....	14	50
Oil Exploration	300	1	21	44
*Pyrite	99	....	4	26
Talc	4	....	....	....
Tanto-Columbite	9	....	....	....
*Tin	104	....	1	....
Rock Quarries	258	....	3	6
Totals	8,041	8	432	1,697

* Indicates effective workers only.

Accidents classified according to causes for the various districts are shown in Table " C."

TABLE C

Fatal and Serious Accidents showing Causes and Districts

District	Explosives		Falls		Shafts		Fumes		Miscellaneous Underground		Surface		Total	
	Fatal	Serious	Fatal	Serious	Fatal	Serious	Fatal	Serious	Fatal	Serious	Fatal	Serious	Fatal	Serious
Kimberley	....	....	....	....	....	....	....	....	....	....	1	....	1	....
West Kimberley	....	....	....	....	....	....	....	....	....	1	....	7	....	8
Pilbara	....	....	....	....	....	....	....	....	....	....	....	3	....	3
West Pilbara	....	1	....	1	....	....	....	....	....	8	....	6	....	16
Ashburton	....	....	....	....	....	....	....	....	....	....	....	11	....	11
Peak Hill	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Gascoyne	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Murchison	....	....	....	2	....	2	....	....	1	12	....	7	1	23
East Murchison	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Yalgoo	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Northampton	....	....	....	....	....	....	....	....	....	1	....	1	....	2
Mount Margaret	....	....	....	....	....	....	....	....	....	....	....	1	....	1
North Coolgardie	....	....	....	....	....	1	....	....	....	4	....	1	....	6
Broad Arrow	....	....	....	....	....	....	....	....	....	....	....	....	....	....
North-East Coolgardie	....	....	....	....	....	....	....	....	....	....	....	....	....	....
East Coolgardie	....	5	3	12	....	5	....	1	2	181	....	27	5	231
Coolgardie	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Yilgarn	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Dundas	....	2	....	3	....	....	....	....	....	20	....	8	....	33
Phillips River	....	....	....	....	1	....	....	....	....	3	....	3	1	6
Greenbushes	....	....	....	....	....	....	....	....	....	....	....	....	....	....
South-West	....	....	....	1	....	....	....	....	....	3	....	33	....	37
Collie	....	....	....	6	....	....	....	....	....	40	....	9	....	55
Total for 1964	....	8	3	25	1	8	....	1	3	273	1	117	8	432
Total for 1963	....	5	....	30	....	8	....	....	1	281	2	121	3	445

FATAL ACCIDENTS

A brief description of fatal accidents reported during the year is given below.

Name and Occupation	Date	Mine	Details and Remarks
Kakousidis, Dimitrious (Miner)	22/1/64	Paringa South Shaft, Gold Mines of Kalgoorlie (Aust.) Ltd.	Buried in a run of ore whilst inspecting a suspected defective break through to a chute. Death due to shock.
Kelsall, Possy (Relieving Shift Boss)	17/2/64	Perseverance Shaft of Gold Mines of Kalgoorlie (Aust.) Ltd.	Old ladder way broke away and victim fell down winze and into water. Cause of death was asphyxiation by water whilst apparently unconscious.
Dalley, Richard John (Pumpman)	9/3/64	Lake View and Star Gold Mines Ltd.—Chaffers Shaft	Suffered multiple fractures of the skull when he was crushed by a fall of rock caused by an earth tremor.
McGillivray, Hugh Hossack (Miner)	20/4/64	Hill 50 G.M. N.L.	Apparently accidentally fell to bottom of winze, death being due to complete avulsion of the brain.
Sack, Harold Gotthard (Drill Crew)	10/6/64	Bonaparte Gulf Drill Site No. 1	Fell from oil rig after a mishap on a platform 119 feet above ground. Death was due to extensive brain damage.
Starcevic, Mustapha (Mechanical Loader Operator)	26/6/64	Hamilton Shaft of Great Boulder Gold Mines Ltd.	Fall of rock from hanging wall of leading stope caused multiple injuries.
Niemann, Wilhelm (Miner)	19/11/64	Main Shaft of Great Boulder Gold Mines Ltd.	Fall of rock from hanging wall. Death was due to asphyxiation.
Martin, Ronald Vincent (Skipman)	19/11/64	Elverdton Shaft of Ravensthorpe Copper Mines N.L.	Fell from skip which contained drill steel. Apparently drill steel caught in shaft. Death due to severe head injuries.

WINDING MACHINERY ACCIDENTS.

Eleven accidents involving winding machinery, attachments, and guides were reported during the year, and are briefly as follows:—

Fatal.—(1). This accident which is included in the above fatal accidents occurred in the Elverdton Shaft of Ravensthorpe Copper Mines N.L., on 19th November, 1964, when the skipman was ascending in the skip which contained drill steel. The drill steel fouled the shaft timbers causing the skipman to be thrown from the skip, and the skip was damaged.

Overwinds.—(2). On 6th February the driver on the Lake View Shaft Internal Winder misjudged the position of the skip in the shaft and an overwind resulted. As a precaution, the undamaged rope was cut and reshod.

On 17th February another overwind occurred in the same shaft. A driver, new to this winder, failed to reverse the action after discharging a skipload of ore. As a precautionary measure, the rope was cut and reshod.

Cages Hung Up.—(4). It was thought that a faulty wind of the rope caused the grippers to act when men were being lowered in the Main Shaft of Hill 50 Gold Mine N.L. on 13th February. No injuries or damage resulted but the rope was rewound before further use.

When a reconditioned skip was placed in the Croesus Shaft of North Kalgurli (1912) Ltd., on 14th April, on its first run down the shaft the grippers engaged on a new section of "skid". No damage resulted but the skip was removed for further checking.

A displaced piece of shaft lagging caused the grippers to act and a skip to become "hung up" in the Victoria Shaft of Gold Mines of Kalgoorlie (Aust.) Ltd., on 20th July. The skip was descending empty and when the grippers acted, approximately 1,100 feet of rope became coiled in the compartment. The rope was recovered and found to be undamaged. It was necessary to replace two "skids".

A failure in the safety gripper linkage caused a skip to become "hung up" in the same shaft on 29th October. The linkage was renewed.

Cage Out of Control.—(1). On 24th October the power failed to make contact throughout the control of the Hill 50 G.M. Winder. This was corrected, however the gravity brake failed to operate when the power was cut. The left hand cage containing two full trucks was at No. 7 level loading station whilst the right hand cage containing two empty trucks was in the sky shaft. The unbalanced load caused the right hand cage to ascend and the detaching thimble released the rope and supported the cage. No damage resulted but 10 feet was cut from each rope, and reconditioned safety hooks, shackles and cage chains fitted.

Derailments.—(1). The north side skip in the Royal shaft of Central Norseman Gold Corporation N.L. was derailed while descending empty on 29th December. Six end legs and one centre leg were knocked out but the skip was not damaged. It is thought that spillage caused the derailment.

Miscellaneous.—(2). On 3rd January during normal operations, the cast iron teeth on the dog clutch of the Lake View Internal Shaft Winder broke. The winder operations were suspended whilst a spare drum and clutch collar were installed.

A misunderstanding led to a skipman looking over the side of the skip at Timoni Gold Mine on 15th May and when the skip moved his head hit a shaft divider. He received abrasions to his head.

PROSECUTIONS.

It was found necessary to prosecute six persons during the year and prosecutions were successfully completed.

Four men who fired outside the prescribed time of firing were dealt with.

One loco driver who repeatedly left ventilation doors open was prosecuted, as was another man who drilled into a face containing a misfire.

SUNDAY LABOUR PERMITS.

Nine permits, to employ labour on Sundays, were issued during the year. Five of the permits were issued to Gold Mines of Kalgoorlie (Aust.) Ltd. for work in the Mount Charlotte Mine as follows:—

- To remove broken waste rock from the ore pass and enable shaft sinking to be continuous.
- To erect forming for the underground crusher installation.
- To complete the starting set of the ore pass system into the underground crusher and also to transport ore from the stockpile.
- To align and concrete the initial steel ore pass section of the North ore pass.
- To line the base of the ore pass system with rails.

One permit was issued to Central Norseman Gold Corporation to remove cables, pipes, etc., from the Regent shaft to commence a crosscut on No. 19 level.

A permit was issued to North Kalgurli (1912) Ltd. to place slime fill in a leading stope, to stabilise bad ground.

Norseman Gold Mines N.L. was permitted to hoist ore on one Sunday to empty the main ore pass.

Western Titanium N.L. was permitted to mine in the pit for all Sundays from 16th August until 28th December.

AUTHORISED MINE SURVEYORS.

The Survey Board issued three certificates during the year.

CERTIFICATES OF EXEMPTION (SECTION 46).

Twelve certificates were issued.

PERMIT TO CONSTRUCT UNDERGROUND DAM (REGULATION 248).

One permit was issued to North Kalgurli (1912) Ltd. to construct an enclosed dam on the No. 5 level, Oratava workings.

PERMITS TO FIRE OUTSIDE PRESCRIBED TIMES (REGULATION 51).

One permit was issued, to Gold Mines of Kalgoorlie (Aust.) Ltd., to allow for the quicker stripping of the Mount Charlotte service—ventilation shaft. This was in an upcast isolated air flow and the permit provided better overall ventilation and prevented loss of time in subsequent operations.

PERMITS TO RISE (REGULATION 64).

Thirty-seven permits were issued for 78 rises totalling 7,805 feet. Thirty-eight of these rises were constructed using the rising gig method.

ADMINISTRATIVE.

Mines Regulation Act—A notice published in the *Government Gazette* (No. 21) of the 10th March amended Regulation 204 which governs the examination of, and issue of certificates to, persons before they may drive a locomotive underground.

Regulation 14 was amended *(Government Gazette* No. 86 of 15th October) following a review of the wages for Workmen's Inspectors of Mines.

Mining Act—A notice published in *Government Gazette* (No. 12) of 19th February amended Regulation 205F to extend the period of exemption from payment of Royalty by producers of Ilmenite.

Regulation 205B was amended *(Government Gazette* (No. 38) of 29th April) to vary the rates of Royalty payable on certain minerals.

Coal Mines Regulation Act—No amendments were made to this Act during the year.

Mine Workers' Relief Act—The Mine Workers' Relief Act Amendment Act, 1964, was assented to on 14th December 1964. The amendments are primarily of administrative nature.

VENTILATION.

All metalliferous mines throughout the State were inspected during 1964. Dust counts, and temperature and air measurements were made in all working places visited. Inspections were also made of the crushing sections at the hard rock quarries, and the dry treatment plants associated with the heavy mineral sands operations.

Lead-in-air sampling of the Gold Assay Offices was regularly conducted and measures taken to greatly improve overall conditions in these sections.

Assistance was again given freely to any mine to conduct ventilation surveys, or towards the designing of Primary fan installations and dust collection units.

Continuous sampling of exhaust fumes from diesel equipment in use underground at the Mount Charlotte mine has been conducted and recorded.

Work towards further improving ventilation conditions underground and the results from this work will greatly benefit all concerned.

A total of 1,501 air samples were taken and microscopic examination showed an average dust count of 319 p.p.c.c.

Sixty-seven (67) samples taken contained over 1,000 p.p.c.c. Twenty-six (26) of these samples were taken on haulage levels and 19 in surface crushing sections.

The average dust count was higher than the average of 247 p.p.c.c. recorded in 1963. This increase was due to more active development from producing areas, extraction of ore from old stopes, and more frequent inspections in mines away from Kalgoorlie, (especially the asbestos plants), and hard rock quarry crushing sections. As a result of the inspections, the various operating companies have spent considerable sums of money in installing dust collection units.

All alleged fuming accidents reported to our Ventilation Section were investigated. Although 22 such accidents were reported and investigated it was found that only 8 of these resulted in time lost, and that in several instances there were no indications of fumes in the areas, nor did the patient show any symptoms of fuming.

Towards the end of the year it was found that Hydrogen Sulphide gas was being produced when blasting agents or Nitroglycerine explosives were exploded in the course of mining in some ore bodies. Initial tests have indicated that the generation of this gas is not new to our mining, but that the more modern testing equipment now available has allowed us to determine the presence of the gas. Extensive testing is being undertaken, but the presence of the gas does not provide undue concern as it can be easily dissipated by adequate ventilation.

Eight reports of Methane gas flows of a minor nature were received and investigated. Seven of the occurrences involved diamond drill holes being drilled in the areas worked by North Kalgurli (1912) Ltd., and Gold Mines of Kalgoorlie (Aust.) Ltd., and one small flow was encountered by diamond drilling at Hill 50 G.M. One suspected "flow," from an old winze, was considered to be Hydrogen Sulphide gas caused by stagnant water in the winze.

It is with pleasure that I report that for the eighth year in succession there has not been a fatal accident due to the fumes from explosives.

Aluminium Therapy—As the result of a ballot conducted amongst mine workers in April, 1964, the prophylactic treatment with aluminium powder was continued.

GROUND VIBRATION.

The Department's Sprengnether Portable Blast and Vibration Seismograph was used during the year to ensure that blasting operations were conducted in a manner to prevent damage to property. Measurements of vibrations were made in relation to blasting operations at the Geraldton harbour outer approach channel, the Geraldton harbour inner approach channel, the shale quarries adjacent to the R.A.N. Armament Depot at Byford, at Limestone quarries in the Fremantle area, a Granite quarry at Orange Grove, and in test work in relation to harbour work.

GOLD MINING.

The ore treated during the year amounted to 2,645,956 tons as compared with 2,770,166 tons in the previous year. Gold recovered amounted to 715,481 fine ounces as compared with 802,860 fine ounces for 1963.

Grade of ore mined was lower, recovery being 5.408 dwts. per ton as against 5.80 dwts. per ton for 1963.

The calculated value of the gold produced was £11,191,180, which included £11,709 distributed by the Gold Producers' Association from the sale of 556,658 fine ounces of gold at an average premium of 5.048 pence per fine ounce.

The Mint value of gold throughout the year was £15 12s. 6d. per fine ounce.

There was a decrease in the number of men employed in the industry from 5,297 in 1963 to 4,785 in 1964. This resulted from the cessation of operations at Great Western Consolidated N.L., The Sons of Gwalia Ltd., and Eclipse Gold Mines N.L. Average production of ore per man was 553 tons valued at 84.59 shillings per ton as compared with 523 tons valued at 90.66 shillings per ton for 1963. Gold recovery per man averaged 149.52 fine ounces as compared with 151.56 fine ounces in the previous year.

Statistics relating to the gold mining industry are tabulated as follows:—

- Table "D"—Gold Production Statistics.
- Table "E"—Classification of Gold Output, for 1964 by Goldfields.
- Table "F"—Mines that have produced 5,000 ounces and upwards in any one of the past five years.
- Table "G"—Development Footages.

TABLE D

Gold Production Statistics

Year	Tons Treated (2,240 lb.)	Total Gold Yield	Estimated Value of Yield	Value of Yield per ton	Number of Men Employed	Average Value of Gold per oz.	Average Yield per ton of Ore
	Tons	Fine oz.	£A	Shillings A		Shillings A	Dwts.
1935	1,909,832	646,150	5,676,679	59·45	14,708	175·71	6·77
1936	2,492,034	852,422	7,427,687	59·61	15,698	174·27	6·84
1937	3,039,608	1,007,289	8,797,662	57·99	16,174	174·68	6·64
1938	3,759,720	1,172,950	10,409,928	53·38	15,374	177·50	6·24
1939	4,095,257	1,188,286	11,594,221	56·62	15,216	195·14	5·80
1940	4,291,709	1,154,843	12,306,816	57·35	14,594	213·15	5·38
1941	4,210,774	1,105,477	11,811,989	56·10	13,105	213·70	5·25
1942	3,225,704	845,772	8,840,642	54·81	8,123	209·04	5·24
1943	2,051,011	531,747	5,556,736	54·19	5,079	209·00	5·19
1944	1,777,128	472,588	5,966,451	55·89	4,614	210·18	5·32
1945	1,736,952	469,906	5,025,039	57·86	4,818	213·87	5·41
1946	2,194,477	618,607	6,657,762	60·70	6,961	215·25	5·64
1947	2,507,306	701,752	7,552,611	60·25	7,649	215·25	5·59
1948	2,447,545	662,714	7,132,748	58·28	7,178	215·25	5·42
1949	2,468,297	649,572	7,977,200	64·64	6,800	245·62	5·26
1950	2,463,423	608,633	9,428,745	76·55	7,080	309·83	4·94
1951	2,471,679	648,245	10,042,392	81·26	6,766	309·83	5·25
1952	2,626,612	727,468	11,809,047	89·92	6,394	324·66	5·54
1953	3,169,875	823,331	13,290,100	83·85	6,359	322·84	5·20
1954	3,240,378	861,992	13,492,209	83·27	6,128	313·04	5·32
1955	2,865,048	834,326	13,055,574	91·13	5,845	312·96	5·82
1956	2,870,273	813,617	12,724,923	88·67	5,612	312·80	5·67
1957	2,951,011	849,741	13,304,752	90·17	5,385	313·15	5·76
1958	3,021,072	874,819	13,674,193	90·53	5,352	312·62	5·79
1959	2,959,202	860,969	13,453,808	90·93	5,769	312·52	5·82
1960	3,056,445	869,966	13,593,462	88·95	5,430	312·51	5·69
1961	2,984,458	870,658	13,684,867	91·71	5,337	314·36	5·83
1962	2,989,653	860,039	13,444,861	90·10	5,353	312·66	5·75
1963	2,770,166	802,860	12,557,034	90·66	5,297	312·81	5·80
1964	2,645,956	715,481	11,191,100	84·59	4,785	312·83	5·408

TABLE E

Classification of Gold Output for 1964 by Goldfields

Goldfield	Unclassified Sundry Claims, Alluvial, etc.	Up to 500 ozs.		501–1,000 ozs.		1,001–10,000 ozs.		10,001–50,000 ozs.		Over 50,000 ozs.		Total
		No. of Producers	Gold	No. of Producers	Gold	No. of Producers	Gold	No. of Producers	Gold	No. of Producers	Gold	
	fine oz.		fine oz.		fine oz.		fine oz.		fine oz.		fine oz.	fine oz.
Kimberley	....	1	15	....	....	....	....	....	....	....	....	15
West Kimberley	....	....	....	....	....	....	....	....	....	....	....	....
Pilbara	618	7	350	....	....	....	....	....	....	....	....	968
West Pilbara	....	....	....	....	....	....	....	....	....	....	....	....
Ashburton	1	....	....	....	....	....	....	....	....	....	....	1
Peak Hill	18	....	....	....	....	....	....	....	....	....	....	18
Gascoyne	1	1	310	....	....	....	....	....	....	....	....	311
Murchison	764	14	1,097	....	....	....	....	....	....	1	69,553	71,414
East Murchison	333	6	514	....	....	....	....	....	....	....	....	847
Yalgoo	....	....	....	....	....	....	....	....	....	....	....	....
Mount Margaret	313	6	596	....	....	....	....	....	....	....	....	909
North Coolgardie	250	15	829	....	....	2	2,393	1	14,386	....	....	17,858
Broad Arrow	373	12	928	....	....	1	1,726	....	....	....	....	3,027
North-East Coolgardie	90	2	83	....	....	....	....	....	....	....	....	173
East Coolgardie	1,190	22	1,825	2	1,363	1	1,151	1	16,216	4	488,239	509,984
Coolgardie	1,711	19	723	....	....	1	1,574	....	....	....	....	4,008
Yilgarn	627	11	1,211	1	946	....	....	....	....	....	....	2,784
Dundas	194	1	331	....	....	....	....	....	....	1	100,340	100,865
Phillips River	....	....	....	....	....	1	2,210	....	....	....	....	2,210
South-West	87	....	....	....	....	....	....	....	....	....	....	87
State Generally	2	....	....	....	....	....	....	....	....	....	....	2
Totals	6,572	117	8,812	3	2,309	6	9,054	2	30,602	6	658,132	715,481
Production, 1963	5,651	108	6,392	2	1,207	8	27,136	3	61,136	6	701,338	802,860
Production, 1962	5,712	100	6,788	4	3,180	7	23,434	2	39,655	7	781,270	860,039
Production, 1961	6,829	109	7,842	5	3,140	8	30,699	2	45,443	7	776,705	870,658
Production, 1960	6,507	135	10,565	3	1,922	9	28,512	2	47,574	7	774,886	869,966

TABLE F

Mines that have Produced 5,000 ozs. and Upwards in any One of the Past Five Years

Mine	1964			1963			1962			1961			1960		
	Tons Treated	Fine ozs.	Dwts. per ton	Tons Treated	Fine ozs.	Dwts. per ton	Tons Treated	Fine ozs.	Dwts. per ton	Tons Treated	Fine ozs.	Dwts. per ton	Tons Treated	Fine ozs.	Dwts. per ton
Central Norseman Gold Corporation N.L.	181,814	100,340	11·038	189,248	102,702	10·85	181,834	109,506	12·04	175,124	98,305	11·23	190,679	101,291	10·62
Eclipse Gold Mines N.L.	....	....	....	4,449	4,567	20·53	6,086	6,757	22·21	8,550	7,860	18·39	6,969	7,690	22·07
Gold Mines of Kalgoorlie (Aust.) Ltd.	704,369	146,366	4·155	527,680	141,837	5·38	518,747	140,919	5·43	518,244	152,964	5·90	569,116	150,319	5·28
Great Boulder Gold Mines Ltd.	425,292	111,415	5·239	450,249	118,520	5·26	450,192	121,628	5·40	452,145	129,388	5·72	448,398	123,875	5·52
Great Western Consolidated N.L.	....	....	....	124,062	15,159	2·44	390,462	61,352	3·14	390,700	58,477	2·99	390,353	63,434	3·25
Hill 50 Gold Mines N.L.	185,232	69,553	7·51	162,558	78,196	9·62	165,698	87,196	10·52	157,196	82,953	10·55	156,844	82,988	10·58
Lake View and Star Ltd.	683,488	164,387	4·81	690,537	168,170	4·87	694,054	172,001	4·96	681,108	166,031	4·88	683,950	165,032	4·83
North Kalgurli (1912) Ltd.	379,630	82,602	4·35	371,967	85,908	4·62	368,350	84,559	4·59	373,795	90,220	4·83	372,053	87,841	4·72
State Batteries	43,967	12,521	5·695	43,944	13,236	6·02	48,154	13,697	5·69	40,673	13,835	6·80	39,219	14,704	7·50
The Sons of Gwalia Ltd.	....	....	....	159,651	31,344	3·93	121,773	25,950	4·26	135,995	32,947	4·85	138,618	32,983	4·76
Timoni (Moonlight Wiluna G.M. Ltd.)	29,353	14,386	9·80	28,914	14,633	10·12	24,493	13,705	11·19	23,871	12,496	10·47	29,880	14,591	9·77
Total	2,633,145	701,570	5·328	2,753,259	774,272	5·62	2,969,843	837,270	5·64	2,957,401	845,476	5·72	3,026,079	844,748	5·58
Other Sources (excluding large Retreatment Plants)	12,811	10,263	16·02	16,907	17,106	20·24	19,810	10,841	10·94	27,057	13,131	9·71	30,366	12,613	8·31
Total (excluding large Retreatment Plants)	2,645,956	711,833	5·36	2,770,166	791,378	5·71	2,989,653	848,111	5·67	2,984,458	858,607	5·75	3,056,445	857,361	5·61
Lake View and Star Retreatment	....	1,048	....	....	9,222	....	....	9,094	....	....	8,339	....	....	9,187	....
State Batteries Tailings Treatment	....	2,600	....	....	2,260	....	....	2,834	....	....	3,712	....	....	3,418	....
Grand Total	2,645,956	715,481	5·408	2,770,166	802,860	5·80	2,989,653	860,039	5·75	2,984,458	870,658	5·83	3,056,445	869,966	5·69

TABLE G

Development Footages Reported by the Principal Mines

Gold or Mineral Field	Mine	Shaft Sinking	Driving	Cross Cutting	Rising and Winzing	Exploratory Drilling	Total
		feet	feet	feet	feet	feet	feet
Gold—							
Murchison	Hill 50 Gold Mines N.L.	399	3,872	1,339	1,886	12,119	19,615
	Eclipse Gold Mines N.L.—Pinnacles G.M.	....	800	....	....	....	800
Coolgardie	Mount Mine	....	....	....	....	2,400	2,400
North Coolgardie	Timoni (Moonlight Wiluna G.M. Ltd.)	....	770	197	215	....	1,182
East Coolgardie	Lake View and Star Ltd.	....	23,910	3,651	5,649	32,548	65,758
	Great Boulder Gold Mines Ltd.	....	14,805	1,372	3,305	8,873	28,355
	North Kalgurli (1912) Ltd.	286	14,850	1,681	2,596	25,245	44,658
	Gold Mines of Kalgoorlie (Aust.) Ltd.	215	16,325	4,070	5,330	42,822	68,762
Yilgarn	Radio	50	122	....	45	....	217
	Hill 50 G.M.—Francis Furness option	413	38	88	....	880	1,419
Dundas	Central Norseman Gold Corporation N.L.	....	6,009	760	2,328	42,064	51,161
	Norseman Gold Mines N.L.	....	....	....	....	3,327	3,327
	Total in Gold Mines	1,363	81,501	13,158	21,354	170,278	287,654
Asbestos—							
West Pilbara	Australian Blue Asbestos	....	4,341	....	941	13,263	18,545
Pilbara	S. H. Stubbs—Soansville & Lionel	185	203	....	125	....	513
	Total in Asbestos Mines....	185	4,544	....	1,066	13,263	19,058
Pyrite—							
Dundas	Norseman Gold Mines N.L.	....	661	210	256	....	1,127
Copper—							
Phillips River	Ravensthorpe Copper Mines N.L.	....	856	....	45	4,636	5,537
Ashburton	Westfield Minerals (W.A.) Ltd.	50	....	....	....	....	50
Peak Hill	New Consolidated Goldfields—Thaduna	....	....	....	....	4,834	4,834
West Pilbara	Westfield Minerals (W.A.) Ltd.	....	....	....	....	2,214	2,214
	Total in Copper Mines	50	856	....	45	11,684	12,635
Iron—							
Ashburton	B.H.P. Ltd.	300	....	....	....	....	300
West Pilbara	Mt. Newman Iron Co.	....	1,100	....	....	26,521	27,621
Yilgarn	Mount Jackson	450	....	900	....	....	1,350
	Total in Iron Mines	750	1,100	900	....	26,521	29,271
Manganese—							
Pilbara	Woodie Woodie project	....	....	....	....	576	576
	Total in All Mines	2,348	88,662	14,268	22,721	222,322	350,321

OPERATIONS OF THE PRINCIPAL MINES

EAST COOLGARDIE GOLDFIELD.

The total ore treated in this goldfield amounted to 2,207,827 tons with a recovery of 509,984 fine ounces of gold at an average of 4.62 dwt. per ton. This output was equal to 71.28 per cent. of the gold production of the State. In the previous year 2,040,505 tons of ore averaging 5.21 dwt. were treated for a recovery of 531,102 fine ounces of gold.

Production in the *Bulong District* amounted to 512 fine ounces from 139 tons of ore.

In the *East Coolgardie District* 509,472 fine ounces were recovered from the treatment of 2,207,688 tons of ore. Following are notes on the activities of the principal producers in the district.

Lake View & Star Ltd., with a return of 164,387 fine ounces of gold recovered from 683,488 tons of ore treated, maintained its position as the State's leading producer. Retreatment of tailings yielded an additional 1,048 fine ounces.

The previous year's production was 168,170 fine ounces from the treatment of 690,537 tons plus 9,222 fine ounces from tailings retreatment.

Estimated ore reserves as at 1st July were 3,584,500 short tons of an average grade of 4.82 dwt.

Development work completed during the year amounted to 33,210 feet.

Shaft sinking operations to extend the Lake View Shaft from the 2,300 feet to 2,800 feet level were completed. The shaft has yet to be sunk to a loading station and sump at 2,900 feet level.

Mill extensions have increased the capacity of the plant to a maximum of 920,000 tons per year.

Successful testing on a plant scale for an improved recovery by more vigorous agitation at a lower pulp density in the post-cyanidation section has led to installation of the necessary equipment to maintain these conditions at full tonnage throughput.

The hydraulic fill system of mining has been extended and this method of stoping supplies 22.8 per cent. of total ore production.

Gold Mines of Kalgoorlie (Aust.) Ltd., increased production and from a total of 704,369 tons of ore treated, 146,366 fine ounces of gold were recovered, giving an average of 4.155 dwt. per ton.

The year was marked by the bringing into production of the Mount Charlotte leases from which leases the treatment of 120,450 tons of free milling ore produced 16,216 fine ounces of gold. The recovery of 2.7 dwt. per ton of ore ensures profitable mining. Cut and fill methods of mining are employed, the fill consisting of dry residues and gravel. All ore is taken to the ore passes by diesel operated equipment. Shaft sinking below the 700 feet level is in progress. A cryderman mucker has been installed in the shaft sink.

A strong development programme was continued on the Fimiston group of leases.

Ore reserves are estimated at 3,849,500 tons averaging 4.09 dwt. fine gold per ton.

Development work amounted to 25,940 feet.

Great Boulder Gold Mines Ltd., treated 425,292 tons of ore for a recovery of 111,415 fine ounces of gold, an average of 5.239 dwts. per ton. During the previous year 450,249 tons of ore yielded 118,520 fine ounces of gold, average recovery being 5.26 dwts. per ton. Development which has been confined to known lode channels amounted to 19,482 feet and included 14,805 feet of driving.

Ore reserves at 30th June were estimated to be 2,002,800 tons of an average value of 5.25 dwts. fine gold per ton.

North Kalgurli (1912) Ltd. increased its tonnage but there was a decrease in gold recovered. The figures of 379,630 tons treated for a recovery of 82,602 fine ounces of gold represent an increase of 7,633 tons and a decrease of 3,304 fine ounces in relation to the previous year.

Development during the year totalled 19,413 feet which included 286 feet shaft sinking and 14,850 feet driving.

Ore reserves estimated as at 23rd March are written at 3,849,580 tons averaging 4.09 dwts. fine gold per ton.

The Kalgurli shaft was deepened two lifts and levels established. Development of these levels, which will be in calc schist, will proceed in 1965.

At the *Hannans North Mine*, tributers produced 2,894 tons ore which was treated at the Kalgoorlie State Battery for a recovery of 531 fine ounces of gold. They have since ceased operations.

The *Daisy Gold Mine* at Mount Monger worked on high grade ore between No. 7 and No. 6 levels and 1,291 tons of ore treated at the Kalgoorlie State Battery yielded 1,151 fine ounces of gold.

Work at the *Rose Marie G.M.* was confined to hoisting the "seconds". A recovery of 360 fine ounces of gold was obtained from crushing 2,786 tons.

DUNDAS GOLDFIELD.

The production of 100,864 fine ounces of gold from the treatment of 182,515 tons of ore represented 14.1 per cent of the State's total production but a decrease from the previous year of 7,327 tons and 2,087 fine ounces.

Central Norseman Gold Corporation N.L. treated 181,814 tons for a recovery of 100,340 fine ounces of gold. Gold recovery averaged 11.038 dwts. per ton as compared with 10.85 dwts. per ton the previous year.

Ore reserves are estimated at 670,500 tons at 10.0 dwts. per ton.

This mine which employs 375 men continued development at a rate of 1 foot per 20 tons of ore treated and a total of 9,097 feet was completed.

The diamond drilling programme proceeded at an increased rate and 35,257 feet of surface drilling and 6,807 feet of underground drilling were completed. The No. 22 level south drive off the Regent Shaft was advanced to test ore in the vicinity and at the end of the year this drive face was more than 8,500 feet from the shaft.

A winze was commenced from No. 29 level Regent shaft and it is intended that this winze will explore the ground a further 1,000 feet at an inclination of 27 degrees.

The No. 22 level off the Royal Shaft was advanced to about 2,700 feet from the shaft to investigate a shear.

Norseman Gold Mines N.L. completed a total of 3,327 feet of diamond drilling in their surface gold exploration programme.

Prospectors at *Beete* produced 594 tons of ore which yielded 346 fine ounces gold when treated at the Norseman State Battery.

MURCHISON GOLDFIELD.

The production of 190,077 tons of ore from this goldfield represented an increase of 18,994 tons over the previous year, but the recovery of 71,414 fine ounces gold was a decrease of 12,287 fine ounces. The gold yield represented 9.98 per cent of the State's total.

Gold output from various tenements in the *Cue District* amounted to 410.60 ounces from the treatment of 1,190.25 tons of ore; 1,129.25 tons and 271.02 fine ounces coming from the Reedy centre.

In the *Day Dawn District*, Day Dawn Gold Pty. Ltd., further investigated their mine to a limited degree.

Eclipse Gold Mines N.L., continued their investigations of the Pinnacles Mine and 800 feet of driving was completed at an underlay depth of 370 feet.

In the *Meekatharra District* 3,081.25 tons of ore were treated. Gold produced amounted to 1,066.52 fine ounces but as 552.56 of these were obtained by State Battery tailings treatment, it will be evident that only low grade "shows" were worked.

The *Mount Magnet District* produced 69,868 fine ounces of gold from the treatment of 185,625 tons of ore. The principal producer was *Hill 50 Gold Mines N.L.* with 69,553 fine ounces gold from 185,232 tons. Average recovery was 7.51 dwts. per ton. Corresponding figures for the previous year were 78,196 fine ounces from 162,558 tons averaging 9.62 dwts. per ton.

The Main shaft was deepened a further 399 feet to a total depth of 2,873 feet. No. 12 level plat was cut and ore passes installed to the No. 12 loading station.

Development Footage totalled 7,496 feet, the majority being completed below No. 11 level where an exploration programme to establish the presence of an extension of the main ore body at depth was progressing.

Development footages reported include work done on the Brownhill mine where some level development and stope preparation was undertaken. Some ore from this mine was carted to the Main Shaft and treated, and a stockpile also established on the surface from ore obtained from development.

The Crydeman shaft mucker was used in shaft sinking operations.

Electric locomotive haulage has been installed in the underground workings, initially on No. 11 level.

The power house was extended and a Ruston 6 VLBX engine, a 1000 K.W. alternator and a 2000 c. ft. Bellis and Morcom compressor with a 400 H.P. electric motor installed.

Two filter presses and a rotary furnace were installed in the "gold room" of the treatment plant.

EAST MURCHISON GOLDFIELD.

The production of 1343.00 tons of ore on treatment yielded 847.38 fine ounces gold. The *Goanna Patch* in the Lawlers District was the only centre attracting constant activity. The majority of prospectors here are Aboriginal Natives. Western Mining Corporation Ltd. are actively interested in the field and give practical assistance to the Natives. This centre yielded 698.17 fine ounces gold when 1164.00 tons of ore were treated at the Darlot State Battery.

MOUNT MARGARET GOLDFIELD.

The total ore treated in this goldfield amounted to only 2,536 tons. This returned a yield of 908.91 fine ounces gold. In 1963, the output of this goldfield represented 4% of the State's total gold yield.

Cleaning up operations at the *Sons of Gwalia Ltd.* resulted in the recovery of 440.46 fine ounces gold but the closure of this mine at the end of 1963 and the subsequent decrease in population adversely affected the number of prospectors in the surrounding centres.

At Lake Darlot, the *Monte Christo* produced 100.01 fine ounces from 1372.50 tons ore. The "grade" of this ore is diminishing.

In the *Mount Malcolm District* other prospectors worked at Leonora, Cardinia, Mertondale and Freeman's Find centres.

There was no reported production from the *Mount Margaret District* and only 46.02 fine ounces from sundry claims in the *Mount Morgans District.*

NORTH COOLGARDIE GOLDFIELD.

Production from this goldfield amounted to 17,857.73 fine ounces gold recovered from 34,860.50 tons of ore.

In the previous year 18,356 fine ounces gold were obtained from 34,928 tons of ore. The output from this goldfield represented 2.49 per cent. of the State's total.

In the *Menzies District* the principal producer was Moonlight Wiluna Gold Mines Ltd. operating the *Timoni Gold Mine* at Mount Ida. From this mine 14,386.42 fine ounces gold were obtained from 29,353 tons of ore averaging 9.802 dwt. per ton. Ore reserves are given as 11,190 tons broken in stopes plus 15,300 tons probable; no values are given. Development work at this mine totalled 1,182 feet made up of 770 feet driving, 197 feet crosscutting, 170 feet rising and 45 feet winzing. Exploration work was undertaken southwards on the 400 feet level and north of the main north fault on the same level where an ore zone has been encountered.

Prospecting in this district was maintained at a steady rate, the production from the principal small mines being:

- First Hit Gold Mine—41.47 fine ounces from 282.75 tons.
- Goodenough Gold Mine—11.07 fine ounces from 124.00 tons.
- Black Swan Gold Mine—25.70 fine ounces from 322.75 tons.
- Callie Gold Mine—60.55 fine ounces from 219.00 tons.
- Little Wonder Gold Mine—8.01 fine ounces from 111.00 tons.
- Good Block Gold Mine—13.32 fine ounces from 326.00 tons.
- Flying Fish Gold Mine—22.94 fine ounces from 152.25 tons.

In the *Ularring District* a total of 1,762.84 fine ounces gold was produced. Of this total the *"Oakley" Gold Mine* contributed 1,205.39 fine ounces; however only 278.43 fine ounces were obtained from the 200 tons of ore treated during the year, the balance of 926.96 fine ounces being recovered by the sale to Gold Mines of Kalgoorlie (Aust.) Ltd. of accumulated sands. At Morley's Find the *First Hit Gold Mine* produced 187.03 fine ounces from 129.75 tons, and the *Mabel Gertrude Mine* 96.74 fine ounces from 90.75 tons ore. At the *Mulwarrie* centre a small but rich crushing of 13.5 tons yielded 147.90 fine ounces gold from the *Four Mile* mine, and at the *Golden Wonder* at *Mulline* 80.49 fine ounces were won from 60.50 tons ore.

Work at the *Altona Gold Mine* in the *Niagara District* ceased. During the year 296.75 tons of ore yielded 104.56 fine ounces gold. This has for some years been a 'marginal' venture and machinery breakdown hastened the closure.

In the *Yerilla District* 1941 tons were treated for a recovery of 1,218.88 fine ounces gold. Practically all of this production was from the *Yilgangie Queen* from where 1,187.73 fine ounces gold were recovered from 1,702 tons ore. The main ore shoot had become impoverished at depth and mining was concentrated in recovering remnant ore. Exploration failed to locate further payable ore but Western Mining Corporation N.L. began further testing by diamond drilling from the surface.

YILGARN GOLDFIELD.

Production for the year was 2,784.09 fine ounces gold. Ore treated amounted to 4,847.75 tons. The decline occasioned by the cessation of operations in 1963 by Great Western Consolidated N.L. is seen by a comparison of figures for the two preceding years. In 1962, 396,944 tons yielded 65,138 fine ounces which represented 7.6 per cent. of the State's total production, and in 1963, 128,812 tons yielded 17,904 fine ounces or 2.2 per cent. of the State's total production.

A small labour force was maintained at *Great Western Consolidated N.L.* to salvage and dismantle plant. A recovery of 431.31 fine ounces gold was reported from "clean-up" operations. The power plant continued to operate to supply power to the Yilgarn Shire Council.

The *Radio* mine in the Golden Valley centre reported the production of 945.45 fine ounces gold from 1,137 tons of ore. Production was curtailed during shaft sinking and plant modification. The shaft was extended 50 feet to an underlay depth of 600 feet and the driving of No. 12 level has disclosed continuation of the main ore shoot. The installation of a ball mill and modifications to mill circuit has raised the plant capacity to 2,500 tons per year.

The *Marvel Loch* area produced 518.61 fine ounces gold from 2,595.75 tons treated. Included in the above were 149.40 fine ounces recovered from 541 tons of ore broken at the *Frances Furness* Mine. Hill 50 Gold Mine N.L. working under an option agreement sank a new shaft to a depth of 414 feet and from the bottom drilled a series of diamond drill holes.

At Edward's Find, the King Solomon Mine produced 340.99 fine ounces gold from 1693.75 tons of ore crushed at the Marvel Loch State Battery.

At Parker's Range, the *Constance Una* mine was reopened and 219.77 fine ounces of gold were recovered from 154 tons of ore.

COOLGARDIE GOLDFIELD.

During 1964, 4,520 tons of ore were treated for a return of 4,007.43 fine ounces gold. In the previous year 29,717 tons yielded 10,139 fine ounces.

Tributers working a block above the 70 feet level of the *Barbara Mine* at Hampton Plains recovered 232.78 fine ounces gold from 992.5 tons ore crushed.

Paris Gold Mines Pty. Ltd. ceased operations early in the year without any ore breaking being undertaken. The plant clean-up yielded 477.09 fine ounces gold. Concentrates from ore mined in 1963 and forwarded to Japan realised 1,096.66 fine ounces gold from 203.75 tons of gold/copper concentrates. At the *Mount* Mine owned by this company, New Consolidated Goldfields (Aust.) Ltd., under an option agreement, drilled four surface holes.

Numerous prospectors were active in the Coolgardie Goldfield and amongst the smaller producers in the Coolgardie Goldfield the best returns were from the *Little Nipper at Ryan's Find* with 93.69 fine ounces from 26 tons; the *Jackpot* at Coolgardie with 66.20 ounces from 204.75 tons; the *Rayjax* at Bonnievale with 57.33 fine ounces from 46.25 tons; *P.P.L. 486* on Hampton Plains with 43.25 fine ounces from 216.5 tons; and the *Great Lion* at Logan's Find with 38.75 fine ounces from 243.50 tons.

PHILLIPS RIVER GOLDFIELD.

The only producer in this field was *Ravensthorpe Copper Mines N.L.* with 2,209.99 fine ounces gold reported for 1964. Gold was produced as a by-product in copper production. Tonnage treated included 47,303 tons of ore broken, and 17,239 tons of residues from the field giving a total tonnage of 64,542 tons. A total of 4,025 tons of copper-gold-silver concentrate was produced. 5,503.14 fine ounces silver were also reported as being recovered.

Ore breaking was confined to the *Elverdton* workings, the only other underground operations being a little development in the *Marion Martin* mine.

PILBARA GOLDFIELD.

In this goldfield 967.68 fine ounces gold were recovered from 1,422.00 tons of ore treated and the treatment of State Battery sands which yielded 335.66 fine ounces at *Bamboo Creek,* 448 tons of ore were broken from the *Mount Prophecy* mine and yielded 207.10 fine ounces gold. From the same centre 206.50 tons broken in the *Prince Charlie* mine yielded 54.14 fine ounces. The majority of gold won by small producers came from sundry claims.

BROAD ARROW GOLDFIELD.

Total production for the year was 3,027.06 fine ounces gold from the treatment of 15,419.40 tons of ore.

The *Gimlet South* with 1,726.08 fine ounces gold from 13,253.25 tons ore treated was the leading producer. A gradient road into the open cut has been established and mining and carting costs are very low. The *Pride* at *Bardoc* treated 37.25 tons for a yield of 235.16 fine ounces. From the *Bellevue South* 92.50 tons yielded 83.81 fine ounces. At Grant's Patch two small mines were worked. The *Coronation* produced 156 tons which yielded 151.81 fine ounces gold, and the *Prince of Wales* 247.25 tons for 266.41 fine ounces.

The *Sleeping Beauty* at Ora Banda crushed 250 tons for a yield of 43.81 fine ounces gold. The *Rona Lucille* at Paddington crushed 51.50 tons for a recovery of 80.66 fine ounces gold.

GASCOYNE GOLDFIELD.

The *Star Mangaroon* with 310.63 fine ounces gold recovered from 155 tons crushed at the Meekatharra State Battery, was the only producer in this goldfield.

NORTH EAST COOLGARDIE GOLDFIELD.

The production of gold amounted to 173.38 fine ounces recovered from 304.75 tons of ore. Of the total, 68.07 fine ounces were obtained from 200 tons from the *Kanowna Red Hill* mine, and 15.65 fine ounces from 46 tons from Rowe's Find.

KIMBERLEY GOLDFIELD.

The *Ruby Queen* with 15.42 fine ounces from 60 tons was responsible for the total production from this goldfield.

YALGOO GOLDFIELD.

There was no mining in this goldfield and only 0.39 fine ounce sundry gold was reported.

SOUTH-WEST MINING DISTRICT.

The production from this District was 69.50 tons ore which on treatment yielded 86.97 fine ounces gold. The gold was won from sundry claims at both *Lake Grace* and *Burracoppin.*

Other sources within the State produced 24.02 fine ounces.

MINERALS OTHER THAN GOLD.

The production of minerals, other than gold, for 1963 and 1964 is shown in the table below.

	1963		1964	
Mineral	Tons	Value	Tons	Value
		£A		£A
Asbestos—				
Chrysotile	10·13	783	536·19	43,680·50
Crocidolite	11,094·57	1,202,002	10,614·14	1,062,100·15
Barite	....	....	171·70	682·80
Bauxite	....	....	370,784·00	3,531,720·00 (a)
Bentonite	1,197·00	3,874	676·28	1,570·90
Beryl	82·03	11,102	79·84	9,037·60
Building Stone	559·00	5,777	1,058·85	5,813·50
Clays	101,300·04	108,135	103,947·85	107,048·40
Coal	902,494·90	1,985,060	987,419·70	2,339,467·10
Copper—				
Ore and Concentrates....	6,265·75	304,038	4,618·69	275,877·90
Fertilizer Grade	3,234·75	136,200	2,196·69	125,984·95
Felspar	992·00	6,985	1,386·00	9,762·85
Fuller's Earth	....	....	114·00	456·00
Glass Sand	9,926·09	7,555	10,047·00	7,028·55
Gypsum	50,808·28	82,467	44,998·12	53,778·50
Ilmenite	136,879·93	682,067	330,832·70	1,538,175·40
Iron Ore—				
Exported	1,277,613·00	1,266,967	1,280,864·00	1,270,189·00
For Pig	73,384·00	1,036,074	82,843·00	1,101,608·00
Lead Ore and Concentrates	184·93	6,535	3,354·17	92,631·55
Leucoxene	460·00	5,983	643·19	11,893·85
Limestone	27,895·63	33,618	31,639·00	42,650·00
Lithium Ore—				
Petalite	390·02	3,709	208·00	1,591·20
Spodumene....	22·00	270	51·54	1,055·10
Magnesite	6,494·53	44,167	1,574·24	10,019·85
Manganese	39,356·96	512,995	38,823·81	457,338·15
Monazite	1,048·81	43,339	1,317·19	54,474·55
Ochre	212·80	1,278	323·51	1,941·50
Phosphatic Guano	16·00	160	....	....
Pyrite	58,472·31	384,875	58,396·00	368,781·58
Quartz Grit	56·00	43	....	....
Rutile	606·00	18,035	825·51	25,770·60
Scheelite	....	....	4·31	1,173·65
Silver (fine oz.)	203,093·18	116,500	245,557·97	143,841·50
Talc	4,669·15	71,213	5,431·69	75,002·00
Tantalo-Columbite	13·79	23,234	14·57	13,287·50
Tin Concentrates	576·23	408,023	637·04	620,390·85
Zircon	4,572·85	45,802	20,068·72	195,637·50
TOTALS....	....	8,558,865	....	13,601.463·03

(*a*) Value of 117,724·00 tons Alumina derived from Bauxite.

Brief notes on mineral production are given below.

ASBESTOS.

Chrysotile.—Mining operations at both the Lionel and Soansville centres continued. 2,760 cubic yards of ore were mined and this together with 1,800 cubic yards of tailings was treated at the plant at the Comet mine. Reported production from these sources was 463.69 tons fibre valued at £42,158.

Crocidolite.—Australian Blue Asbestos Ltd. at Wittenoom reported a production of 198,844 short tons of ore, for a recovery of 12,243 short tons of fibre. An average of 181 underground and 204 surface workers were employed. An active development programme continued and 4,341 feet of driving was completed. The company again experienced a difficult year brought about by a further extensive roof collapse in the Colonial mine, the difficulty in obtaining regular markets for their fibre, and acute labour shortage. Perhaps the most significant aspect of the year's operations was the progress made with a test area in which a system of longwall stoping and controlled caving was undertaken. This process, which utilises recoverable hydraulic props and a rock scatter pile, gave very encouraging results and is being examined as a possible pattern for future ore extraction. Exploration by drilling, totalling 13,263 feet, was carried out at points ahead of the Colonial mine excavations, along Joffre Creek, at Yampire Gorge, and at Eastern Creek.

BARYTES.

Barytes produced by Universal Milling Co. Pty. Ltd., from Mineral Claim 20N at Chesterfield in the Murchison Goldfield amounted to 171.70 tons valued at £683 f.o.r.

BAUXITE.

Ore mined by Western Aluminium N.L. at Jarrahdale was railed to the refinery at Naval Base, and 370,784 tons of this ore when treated yielded 117,724 tons of alumina valued at £3,531,720. Ore was mined from a shallow excavation with faces up to 15 feet high. It is intended to increase the output of both the mine and the refinery.

BENTONITE.

Bentonite production from Gunyidi and Marchagee, both in the South West Mineral Field, totalled 676.28 tons valued at £1,570.90. Production is seasonal, usually restricted to dry summer months when dry lake deposits may be worked.

BERYL.

The production of Beryl was similar to the previous year; 79.84 tons containing 889.11 units of Beryllium oxide valued at £9,038 were obtained. Production for 1963 was 82 tons, containing 924 units Beryllium oxide valued at £11,102. Beryl was obtained from the Pilbara, Gascoyne, Yalgoo and Coolgardie Goldfields, the producing centres being Warda Warra with 408.78 units, Londonderry with 292.55 units, Mt. Francisco with 159.16 units, Yinnietharra with 18.37 units, and Goodingnow with 13.18 units.

BUILDING STONE.

Thirty-three tons of granite facing stone were reported as being produced at Watheroo and Karlgarin; 8.3 tons of Lepidolite from Ubini; 9.5 tons of Prase from Spargoville; 72 tons of Sandstone from Mount Barker; 115 tons of Dead White Quartz from Gibraltar; 50 tons of Slate from Mundijong; and 771 tons of Spongolite from Ravensthorpe. This production only relates to holdings under the Mining Act and only represents a small fraction of the State's output.

CLAYS.

Reported clay production from the South West Mineral Field and East Coolgardie Goldfield totalled 103,947.85 tons valued at £107,048.40. Clays reported included cement clay, fireclay, Kaolin, White Ball clay, and brick, pipe and tile clay. Output is well in excess of the above tonnage as most of the clay used in the brickmaking industry is obtained from private property and is not reported to this Department.

COAL.

The total output from the Collie Coalfield was 987,419.70 tons valued at £2,339,467.10 at the pit head. Both production and value were in excess of 1963 figures when 902,495 tons valued at £1,985,060 at the pit head were produced. The production for 1964 is the second highest on record and was only exceeded in 1954, when three companies were in operation.

Open cut production of 343,312.5 tons represented 34.7 per cent. of the field's output.

The *Griffin Coal Mining Co. Ltd.* operating the Hebe mine and the Muja open cut produced 581,983 tons. The Hebe mine with an output of 238,670 tons was the second highest deep mine producer. Some of this coal was won from the second working where "bottom coal" was extracted. This operation was successful notwithstanding that the area was affected by the "bend or swallow" in the seam to the left of the main development headings. Plans are in hand to turn the deeper headings away to the right of No. 7 panel and as the headings are driven forward they will rise and better roof and pillar conditions are expected.

Most of the coal won from the Muja open cut, was taken from the Hebe seam in the East Extension area, but 33,991 tons of the total was extracted from the Galatea seam. The quantity of natural overburden removed totalled 1,253,040 cubic yards.

Late in the year overburden was being removed from the Centaur seam on M.L. 455. An active drilling programme on the Muja and Centaur leases continued.

Western Collieries Ltd.—Western No. 2 Mine with an output of 317,220 tons was the largest deep mine producer on the field. The quantity of coal produced here was a record for any deep mine in the field.

One pump bore was put down at a point below No. 5 East Lateral Heading and pumping commenced.

The main development slants which have now been increased to six in number were being driven forward, and No. 1 and No. 2 of these headings are now approximately eighty chains from the surface. The seam in this area is 11 to 12 feet thick.

During the year a drift was put through to the surface from "D" panel in No. 3 West District, and is being used as an intake airway to serve No. 3 West Districts.

Western No. 4 Mine produced 88,217 tons for the year. Two Districts, the South Portal, and the East Portal, where the 11 feet, or No. 1 seam, and the 8 feet or Bottom seam were mined respectively, were worked. One pump bore for drainage purposes was put down.

Towards the end of the year a series of exploration holes were drilled in the outcrop area to the East of the East Portal District.

COPPER.

Copper produced as copper ores and concentrates, metallic by-product, and for fertiliser, valued at £401,863 was reported.

Ravensthorpe Copper Mines N.L.—A total of 64,542 tons, comprising 47,303 tons of ore mined and 17,329 tons of various tailings were treated. Reported production was 4,324.93 tons of concentrates containing 106,886 Copper units valued at £268,648 f.o.b. Esperance. In addition 2,210 fine ounces of gold and 5,503 fine ounces of silver were produced. Ore breaking was confined to the Elverdton shaft workings, the only other underground operations being a little development on the Marion Martin Lease. A diamond drilling programme completed 4,636 feet. Fifteen surface holes totalled 3,932 feet and five underground holes totalled 704 feet. Surface drilling was confined to the Marion Martin group and on the Harbour View line near Kundip.

Paris Gold Mines Pty. Ltd. did not recommence mining operations in 1964. However it was reported that gold/copper concentrates shipped to Japan yielded 46.14 tons of copper valued at £7,230. The concentrates also contained 1,321.57 fine ounces of gold valued at £20,650 and 3,472.63 fine ounces of silver valued at £1,992.

Production of copper ore for use as a trace element in fertilisers was 2,197 tons of an average grade of 17.99% Copper.

Depuch Shipping and Mining Co. Pty. Ltd. operated for only the first three months of the year, before ceasing operations. Some ore was mined from an open cut but the majority was obtained from surface dumps of rejects from earlier mining days. 773 tons of concentrate averaging 20.02 per cent. copper valued at £52,352 were produced.

The *Thaduna Copper Mining Co. Pty. Ltd.*, reported a production of 673 tons of concentrate averaging 19.20 per cent. copper content, valued at £42,708. The ore was mined from various open cuts along the line of lode which are now virtually connected to form one excavation. Trouble was experienced in maintaining a high grade concentrate through graphitic material being floated with copper concentrate.

A flotation plant was erected by *Mr. Lee at Thaduna* and the treatment of ore from M.C's. 65P, and 93P commenced in July. Production totalled 30.87 tons of concentrate averaging 25.53% Copper valued at £2,734.

From the *Glen Ellen Pool* deposit in the Pilbara Goldfield, 292 tons of copper ore valued at £13,379 were produced.

A notable production was that by Aboriginal Natives at Warburton Ranges who produced 29.63 tons of ore averaging 20.04 per cent. copper valued at £1,678.

Producing fields included the Pilbara, West Pilbara, Ashburton, Gascoyne, Murchison, East Murchison, Peak Hill, Yalgoo, Mount Margaret, and Phillips River Goldfields.

FELSPAR.

Australian Glass Manufacturers Co. Pty. Ltd. reported a production of 1,385 tons valued at £9,753 from their quarry at Londonderry. In addition 208 tons of Petalite valued at £1,591 were obtained by hand sorting.

FULLERS EARTH.

Production from Marchagee totalled 114 tons valued at £456.

GLASS SAND.

A total of 10,047 tons valued at £7,029 was obtained from Lake Gnangara deposit.

GYPSUM.

Plaster manufacturers continued to obtain their supplies of raw material from Yellowdine, Lake Brown, Lake Cowcowing, Dongarra and Norseman. Material obtained from these sources amounted to 38,558 tons valued at £37,859. Plaster of Paris reported as manufactured during the year was 21,942 tons from 31,327 tons of Gypsum.

Cement manufacturers obtained 2,238 tons from Nukarni. *Garrick Agnew Pty. Ltd.* recovered from Lake Cowan, 4,202 tons valued at £13,965 for export.

ILMENITE, LEUCOXENE, MONAZITE, RUTILE, ZIRCON.

Sales of ilmenite totalled 330,833 tons valued at £1,538,175. The increased production is shown in a comparison with the previous year when 136,880 tons valued at £682,067 were produced. Minerals associated with Ilmenite returned £287,776, to the producers.

Western Titanium N.L. at Capel produced 177,327 tons of ilmenite assaying 55.24 per cent. titanium dioxide, 514 tons of leucoxene, 603 tons of monazite, 826 tons of rutile and 16,267 tons of zircon. The bulk of the production was from mining in the Nos. 4 and 6 areas which are north of the treatment plant, also some production resulted from mining in No. 5 area, south of the plant. Eleven new type "pinch" launders were added to the Wet concentrating plant. In the Dry plant a number of additions were made, and included the installation of more Magnetic Cross Belt separators, and the removal of the No. 12 Rolls section. An attritioning unit was installed in the secondary Wet plant.

Westralian Oil Ltd., produced 75,746 tons of ilmenite assaying 58.83 per cent. titanium dioxide, 714 tons of monazite, 129.5 tons of Leucoxene, and 3,802 tons of zircon. The contractor continued to mine the company's ore at Yoganup. A Wesserhutte power shovel shifts the overburden, and two draglines load ore on to trucks which feed an apron where the material is sluiced and pumped to the wet concentrating plant. The resulting concentrate is transported to Capel for dry treatment.

Cable (1956) Ltd., increased output, and produced 42,620.9 tons of ilmenite assaying 54.70 per cent. titanium dioxide. The No. 2 Dredge with a capacity of 200 tons per hour and pumping to spiral concentrators was brought into commission about March. Unfortunately a fire destroyed the spirals. At the close of the year extensions to the main building were in progress.

Ilmenite Pty. Ltd., had reduced production due to a "shut down" of the plant for about three months whilst modifications, repairs and alterations were effected. Production amounted to 28,325 tons of ilmenite with an average assay of 54.75 per cent. titanium dioxide.

Western Mineral Sands Pty. Ltd. This company which is the fifth to operate in the field, commenced operations on 1st July and by the end of the year had produced 6,814 tons of ilmenite assaying 53.6 per cent. titanium dioxide. Operations include, digging sand with rear end loaders; Reichhardt concentrators in the wet concentrating plant, and magnetic belt separators in the dry plant. The primary plant is skid mounted in order that it may be moved as required.

IRON ORE.

During the year, *Australian Iron and Steel Ltd.* shipped 1,280,844 tons of iron ore averaging 63.12 per cent. Fe from Cockatoo Island to the Eastern States.

Constructional work was completed at Koolan Island and production was to commence early in 1965. The company employed 456 persons.

There was continued activity around the iron ore deposits throughout the State, and by the close of the year field mapping, testing and general appraisal had established reserves such to allow the major companies to negotiate agreements for the working of the deposits, and the sale of iron ore overseas. At the time of writing reports have been received of successful negotiations regarding deposits at Mount Tom Price, Mount Goldsworthy, Mount Newman, Tallering and Koolanooka Hills. Negotiations in relation to several other deposits are in progress.

The Charcoal Iron and Steel Industry at Wundowie obtained 82,843 tons of iron ore from the Koolyanobbing deposit and produced 47,906 tons of pig iron valued at £1,101,608.

LEAD.

Increased overseas prices for lead concentrates and new metallurgical techniques resulted in a revival of lead mining. Reported production—all from the *Devonian Lead Mine* in the Napier Ranges—totalled 619.50 tons of lead.

Work at the *Devonian Lead Mine* resumed after a lapse of twelve years. Two shipments of ore amounting to more than 7,500 tons were obtained by open-cut methods and the ore was shipped overseas in crude form. The 3,354.17 tons treated overseas during the year yielded 619.50 tons of lead and 825.08 tons of zinc the combined value of which amountd to £92,632. 11,656.46 fine ounces of silver valued at £6,802.4 was also recovered.

Mining in the Northampton field increased considerably but as no finality of sale of lead concentrates produced was reached, production figures are not included in the year's tabulations. The concentration plant operated by the State Batteries Branch treated 2,934.60 tons of ore produced by small mines and recovered 655.25 tons of lead concentrate. Mines being worked included the Nooka Lead Mine, Two Boys Lead Mine, and the Mary Springs Lead Mine.

LIMESTONE.

Production from holdings covered by the Mining Act, totalled 31,639 tons. The total of limestone quarried is not available for publication as a large quantity is obtained from private property and is not reported.

Cockburn Cement Pty. Ltd. and Swan Portland Cement Ltd., continued to obtain limestone from the South Coogee area by surface ripping with bulldozers. Limestone for house foundations was obtained from eight quarries in the Wanneroo area and three in the Beaconsfield area. The large amount of rubble produced is used for road foundations.

The Charcoal Iron and Steel Industry shifted their crushing plant to a new site at Beaconsfield.

There were only three producers burning limestone for lime production.

Agricultural lime was produced at Dongarra, Parry Inlet, and Esperance.

LITHIUM ORE.

Spodumene produced at Ravensthorpe amounted to 51.54 tons valued at £1,055. Hand picking from ore produced at Londonderry yielded 208 tons of Petalite.

MAGNESITE.

The only reported production of magnesite for the year was by Magnesite (W.A.) Pty. Ltd. who sold 1,574 tons valued at £10,020.

MANGANESE.

Production reported by *Mount Sydney Manganese Pty. Ltd.*, and *Westralian Ores Pty. Ltd.* and exported from Port Hedland totalled 37,922 tons of metallurgical grade ore valued at £446,664. The ore was produced in the Woodie Woodie-Mt. Cooke localities.

Westralian Ores Pty. Ltd. sold 304 tons of Battery grade manganese assaying 70 per cent. MnO_2, valued at £5,928 from their stockpile near Peak Hill, and 598 tons of low grade manganese ore valued at £4,746 from their stockpile at Horseshoe. The company conducted no mining work during the year.

OCHRE.

Red oxide was mined by *Universal Milling Co. Pty. Ltd.* in the Weld Range and 324 tons valued at £1,942 was reported as being produced.

PYRITE.

Norseman Gold Mines N.L., treated 76,612 tons pyrite ore through their Heavy Media Separation Plant and by flotation, and railed 34,511 tons of concentrates to superphosphate works in the metropolitan area. The sulphur content was reported as 16,504 tons valued at £275,053. Most of the mining was carried out above the No. 7 level with cleaning up and pillar extraction continuing above the No. 6 level. Ore reserves are written as 2,436,000 tons.

Gold Mines of Kalgoorlie (Aust.) Ltd. forwarded to works at Fremantle, 23,885 tons of auriferous pyritic concentrate containing 7,498 tons of sulphur valued at £93,729. This was a by-product of gold mining.

SILVER.

Silver produced as a by-product of gold mining amounted to 228,398 fine ounces; as a by-product of lead mining, 11,656 fine ounces; and as a by-product of copper mining, 5,503 fine ounces. The total production was valued at £143,842.

TALC.

Open cut mining operations were continued by *Three Springs Talc Pty. Ltd.* and 5,432 tons of talc valued at £75,002 were sold.

TANTALO-COLUMBITE.

Fourteen and a half tons of concentrate, containing 542.16 units of Ta_2O_5 valued at £13,288 were produced in the State during 1964. The main producing centre was Greenbushes where 11.77 tons were produced as a by-product of tin mining. Other production was reported from the Pilbara 1.37 tons, Warda Warra 1.39 tons, and Yinnietharra 0.04 tons.

TIN.

Production for the year was 637 tons of concentrate containing 446.41 tons of the metal valued at £620,391. This was an increase over the previous year when 576 tons of concentrate produced contained 392 tons of the metal. Tin producers in the Pilbara were responsible for 578.76 tons of the concentrate, the principal producers being *Cooglegong Tin Pty. Ltd.*, with 175.45 tons, *Mineral Concentrates Pty. Ltd.* with 151.66 tons, *J. A. Johnston and Sons* with 122.77 tons, *H. L. Leonard* with 58.04 tons, and *D. D. Mining Co.* with 36.87 tons. In the Greenbushes field, *Austin Bros.* produced 36.19 tons of concentrate, and the *Vulcan Syndicate*, 20.87 tons.

TUNGSTEN ORES AND CONCENTRATES.

Reported production of *Scheelite* concentrate was 4.31 tons containing 311.54 units WO_3 valued at £1,174. The concentrate was produced at Davyhurst, and Tindals near Coolgardie.

J. BOYLAND,
Acting Assistant State Mining Engineer.

APPENDIX NO. 1.

State Mining Engineer:

REPORT ON DRILLING ACTIVITIES FOR YEAR ENDED 31ST DECEMBER, 1964.

An increased footage of more than 5,000 feet has been recorded by the drilling section in the year under review, a total footage of 13,795 against 8,433½ for 1963.

This large increase is clearly shown in the drilling statistics hereunder:

	Feet
1958	10,674½
1959	25,812½
1960	7,368
1961	8,748
1962	8,839
1963	8,433½
1964	13,795

All our machines were in operation at some time during the year throughout the State from Wyndham to Busselton.

During the year the Failing 750 purchased from the Bureau of Mineral Resources was mounted on a Leyland Truck W.A.G. 3344 and now provides a highly mobile unit capable of drilling small holes to 750 feet. This rig has been numbered 10 and was used for five hundred feet of 6 inch cased hole in a Water Resources Survey at Rockingham. Difficulty in obtaining spare parts for this machine has been experienced.

Three of our mobile living quarters for drill crews ("Modern" caravans) have been converted from Kerosene to Kleenheat gas and gas refrigerators installed. The average cost of conversion and installation of refrigerator was £250, this provides a much cleaner and more convenient source of light, cooking and refrigeration.

The two remaining caravans are of Arcus manufacture and could not be converted without major structural alterations.

Four of our rigs No. 3, 5, 6, and 8 were hired for various times during the year and were not under our direct control. The footages done by these machines is not reported and does not show in the return submitted. The recording, issuing and returning of these plants, together with servicing and maintenance on them is a full time job for two men.

Our plants were recalled to the New Government Offices Building in Kings Park Road three times during the year and three different rigs were used. 445 ft. 7 in. in 80 holes through reinforced concrete were completed. With the 10 holes done in 1963 a grand total of 494 ft. 7 in. of boring has been done at this job.

Three new utility type vehicles came into service as replacements for worn out transport. Consideration on the estimates should be given to the replacement of our 4 wheel drive Land Rover and the provision of another light utility for supervision work. A 30 cwt. Dodge truck was extensively damaged due to accident and it is understood has been written off and a replacement is to be ordered.

A "Chamberlain" Mk II Industrial tractor valued at £2,036 was purchased during the year and has proved its value in towing our plants in deep sand at Arrino and Gnangara.

No. 2 Rig (Failing M1) operated for the whole year under hire arrangements to Mr. J. Grill. 5,118 feet were completed by this machine.

One hole at Gosnells for water supply purposes and four in a traverse across the Swan Coastal Plain from Bullsbrook to Wanneroo for ground water resources. This rig was put into service in November, 1952 and has been in operation with very few breaks for the past 12 years and has drilled between 70-80,000 feet. The time is not far distant when this plant must undergo a major refit or possible replacement.

No. 3 Rig (Mindrill A.3000). This plant was hired to Great Oil Drilling Coy. during the year and taken to Derby on an oil exploration programme. Unsatisfactory progress was obtained and the plant returned.

No. 4 Rig (Mindrill A200). 871 feet were drilled by this plant during the year. Most of the footage being in a manganese assessment programme in the Pilbara field.

Rigs 5 and 6 were hired to Associated Diamond Drillers and were used at Thaduna on a copper exploration survey and at Mount Gibson and Mount Newman on iron ore deposits. No footages have been reported.

Rig No. 7 (F20) completed 1724½ feet for the year. This plant is the most suitable for the type of work we are commonly called upon to do. It is light (one ton against four tons for the A.3000 and A.2000) compact and has the capacity for the size and depth of holes required.

Rig No. 8 (E500). This machine was hired to Shark Bay Salt Coy. for portion of the year.

One hundred and ninety-six feet were drilled at the Government Offices Job and for the Harbours and Rivers Department off the Jetty at Busselton.

Rig No. 9 (Gemco) drilled 2,003½ feet for the period under review. 1,250 feet investigating potash occurrences around Dandaragan and Gingin. The balance was drilled in the Bunbury Harbour from a barge determining the contours of the rock bottom to enable estimates of the dredging requirements to be made.

Rig No. 10 (Failing 750) was given a "shakedown" run at Rockingham for water where 500 ft. were completed. A few teething troubles were experienced and some minor modifications were made.

HYDROLOGICAL SECTION.

Ruston Bucyrus percussion rig No. 1 drilled 480 feet for water supply purposes during the year.

No. 2 Rig completed 1,451 feet at Gnangara and Arrino for water.

General.

During the year assistance has been rendered to Government Departments and private firms and individuals in the way of hire or loan of drilling equipment. Listed below is the name of the various parties to have benefited from our resources.

- Australian Blue Asbestos—Drilling equipment.
- P.W.D. (Geraldton Harbour)—Drilling equipment.
- P.W.D. (Fremantle Slipway)—Drilling equipment.
- Shark Bay Salt—Drilling equipment.
- M.W.S. Jarrahdale—Drilling equipment.
- M.W.S. Canning Dam—Drilling equipment.
- Associated Diamond Drillers—Drilling equipment.
- Foundation Engineering Ltd—Drilling equipment.
- Great Oil Drilling Coy—Drilling equipment.
- F. K. Duffy (Cockburn Sound)—Drilling equipment.
- Geophysical Service International—Drilling equipment.
- Darling Range Boring Coy.—Jacks and casing.
- S.E.C.—Bore casing.
- Westphal Bros.—Rock Bits.
- Crawford Quarries—Drilling equipment.
- Artesian Well Drilling Services—Drilling equipment.
- Swan Boring Coy.—Drilling equipment.
- P.W.D. (Capel)—Drilling equipment.
- P.W.D. Geraldton—Drilling equipment.
- New Consolidated Goldfields—Survey equipment.
- W.A.P.E.T.—Fishing equipment.
- University of W.A.—Drilling bits.
- Western Mining Corporation—Drilling equipment.

Tabulated hereunder are the details of work completed for the year.

J. F. HADDOW,
Inspector of Mines (Drilling).

4th March, 1965.

TABLE SHOWING FOOTAGE DRILLED FOR YEAR ENDED, 31st DECEMBER, 1964

Rig. No.	Machine	Place	Purpose	Footage	Total	Basis	Remarks
				ft. in.			
2	Failing M1	Gosnells	Water Supply	463 0		Contract	
		Pinjar	Water Supply	4,655 0		Contract	4 holes
					5,118		
3	A.3000....	Derby	Oil Exploration	....	....	....	Hired
4	A.2000....	Upper Wongong	Dam Foundations	230 11	....	Wages	2 holes
		Govt. Offices	Building Foundation	64 8	....	Wages	18 holes Reinforced Concrete
		Mt. Sydney	Manganese Deposits	250 0	....	Wages	1 hole
		Woody-Woody	Manganese Deposits	325 3		Wages	2 holes
					871		
5	A.2000....	Thaduna	Copper	....	....	....	Hired
6	A.2000....	Mt. Newman	Iron	....	....	....	Hired
		Mt. Gibson	Iron	....	....	....	Hired
7	F.20	South Wongong	Dam Foundation	108 0		Wages	
		Jarrahdale	Dam Foundation	300 6		Wages	2 holes
		Govt. Offices	Building Foundation	334 6		Wages	54 holes Reinforced Concrete
		Ord River	Dam Foundation	826 5		Wages	5 holes
		Nanutarra	Bridge Foundation	155 0		Wages	9 holes
					1,724½		
8	E.500	Shark Bay	Foundation Work....	....	....	....	Hired
		Govt. Offices	Foundation Work....	46 5		Wages	8 holes Reinforced Concrete
		Busselton	Harbour Invest.	149 9		Wages	11 holes
					196		
9	Gemco	Dandaragan	Potash Resources	578 6		Wages	7 holes
		Gingin	Potash Resources	518 0		Wages	6 holes
		Bullsbrook	Potash Resources	155 0		Wages	1 hole
		Bunbury	Harbour Invest.	752 0	2,003½	Wages	68 holes
10	Failing 750	Rockingham	Water Supply	500 0		Wages	2 holes and testing
					500		
			PERCUSSION RIGS				
1	R.B.22R.W.	Gnangara	Water Supply	....	....	Wages	Testing Bore 8
		Arrino	Water Supply	365 0		Wages	
		Kalamunda	Water Supply	....		Wages	Testing Bores
		Rockingham	Water Supply	115 0		Wages	
					480		
2	R.B.22R.W.	Gnangara	Water Supply	144 0		Wages	
		Arrino	Water Supply	1,307 0		Wages	4 holes
					1,451		
				TOTAL :	13,795		

Appendix No. 2.

23rd December, 1964.

The Chairman,

Board of Examiners for Mine Managers' and Underground Supervisors' Certificate,

Mines Department, Perth.

Annual Report.

Herewith I submit the Annual Report on the activities of the Board of Examiners for Mine Managers' and Underground Supervisors' Certificates for the year 1964.

Mining Law Examination.

An examination in Mining Law for the Mine Managers' Certificate of Competency was held on 13th April, 1964.

Details were as follows:—

Entries	11
Admitted	10
Passed	6
Failed	4

The names of the successful candidates were:—

First Class: J. C. Argus, P. G. Fraser, D. J. Vance, F. D. Dykstra.

Second Class: F. R. Morel, R. C. Tarr.

Six (6) copies of the examination papers are attached.

Underground Supervisors' Examination.

The written examination for the Underground Supervisor's Certificate of Competency was held on 8th September, 1964, and attracted applications from the following centres:—

Kalgoorlie	17
Norseman	1
Wittenoom	2
Mt. Magnet	1
	21

Of the twenty-one (21) applications, nineteen were admitted, and eighteen (18) sat for the examination. One candidate in Kalgoorlie did not sit. The results were as follows:—

Examined	18
Passed	13
Failed	5

Certificates of Competency have been issued to the successful candidates whose names are as follows:—

Barrett, C. E.—Kalgoorlie.
Bell, R. L.—Kalgoorlie.
Calvetti, T.—Kalgoorlie.
Devine, W. S.—Kalgoorlie.
Harrison, W. A.—Kalgoorlie.
Knowler, B. A. B.—Kalgoorlie.
Letts, I. R.—Kalgoorlie.
Lucas, G.—Kalgoorlie.
Mainwaring, W.—Kalgoorlie.
Pickering, L. T.—Kalgoorlie.
Faithfull, G. A.—Norseman.
Chapman, J. P.—Wittenoom (restricted to Blue Asbestos Mines, West Pilbara Fields).
Sinclair, W.—Wittenoom.

Six (6) copies of the examination papers are attached.

Mine Managers' Certificates.

Twelve applications for Mine Managers' Certificates were received during the year, details of which are as follows:—

Under the Old Mines Regulation Act:

The following were successful applicants for Certificates of Competency:—

Banks, F. R.
Hug, R. L.
Loxton, I. W.
McNally, R. T.
Powell, P.

Under the New Mines Regulation Act.

The following were successful applicants for the First Class Mine Manager's Certificate:—

Argus, J. C.
Chamberlain, H. I.
Champness, P. A.
Dykstra, F. D.
Vance, D. J.

One application was deferred pending the applicant passing the Mining Law Examination.

There was one successful applicant for the Second Class Mine Manager's Certificate:—

Morel, F. R.

General.

Four meetings of the Board of Examiners were held during the year.

In August, Mr. W. J. Cahill took over duties as secretary, from the then acting secretary, Mr. L. J. Carroll.

The Board of Examiners visited the following centres during the year and examined candidates orally for the Underground Supervisors' Certificate of Competency.

Kalgoorlie, Norseman, Wittenoom.

(Sgd.) W. J. CAHILL,
Secretary, Board of Examiners.

Mines Regulation Act, 1946

Examination for Mine Manager's Certificate of Competency

First Class

MINING LAW

April, 1964

Attempt Six (6) questions from Section A

Attempt Four (4) questions for Section B

Time Allowed—Three (3) Hours.

Candidates should note:—

(a) The Mining Act and Regulations may be used at the examination but Not the Mines Regulation Act.

(b) In answering questions in Section B, reference to the appropriate Sections of the Act or to the Regulations alone will not be sufficient. Candidates must summarise the requirements of the Act and/or Regulations and should also make reference to the relevant section(s) or regulation(s).

(c) Candidates are required to pass in both sections of the paper.

SECTION A

(MINES REGULATIONS ACT AND REGULATIONS)

Attempt Six (6) questions from this section
Do Not attempt more than Six (6) questions from this section.

Marks allowed are Ten (10) per question

What is required by the Mines Regulation Act and/or Regulations regarding the following:—

1. The employment of an:—
   (a) Underground manager.
   (b) Underground supervisor.
2. (a) Times of blasting.
   (b) Boring in butts.
3. (a) Gates to cages.
   (b) Raising or lowering men in a skip.
   (c) Action required when a cage has been idle overnight.
4. (a) Use of tailings for filling stopes.
   (b) Ventilation of development ends.
   (c) Stoppings and doors.
5. (a) What is a serious accident?
   (b) What are the requirements following an accident resulting in serious injuries or apparent serious injuries?
6. (a) Safety provisions for underground locomotives.
   (b) Obtaining a locomotive driver's certificate.
   (c) Diesel engines underground.
7. (a) Ladders in shafts.
   (b) Ladders in winzes.
8. (a) Penthouses.
   (b) Clearing passes and chutes.
   (c) Drawing ore from shrink stopes.

SECTION B

(MINING ACT AND REGULATIONS)

Attempt Four (4) questions from this section

Marks allowed are Ten (10) per question

9. Describe briefly the procedure necessary and circumstances under which applications for:—
   (a) Amalgamation of leases,
   (b) Concentration of labour on Gold Mining Leases,

   can be applied for. State the number of men it is necessary to employ in each case to comply with labour conditions.
10. What action should be taken by the holder of a Mineral Lease if—
    (a) he finds gold on the lease and wishes to recover the gold;
    (b) he desires to mine some mineral other than that specified in the lease.
11. (a) For what purposes may Crown lands be granted as a lease?
    (b) What is the term of a Gold Mining Lease?
    (c) Explain the procedure to be adopted at the end of the prescribed period of a lease if the lessee desires to hold the ground for a further period.
12. (a) You are granted a Gold Mining Lease over Crown land on which machinery erected by the previous lessee still remains. The machinery will interfere with your workings. What action would you take to have the machinery removed?
    (b) A Gold Mining Lease is to be surrendered. What must the lessee do to protect his interest in tailings on the lease?
13. If the owner of pumping machinery considers that his machinery is draining or assisting to drain water from adjacent mines what action can he take to recover some of the pumping costs?

    What costs can he recover?

14. (a) A Mining Lease may extend into a townsite, suburban area or other reserve. What protection does the Act provide for those who have surface rights?
(b) A holder of a pastoral lease builds a dam on his property. How is he protected from miners?

Mines Regulation Act, 1946.

Examination for Mine Manager's Certificate of Competency

Second Class

MINING LAW

April, 1964.

Attempt Seven (7) questions from Section A

Attempt Three (3) questions from Section B

Time Allowed—Three (3) hours

Candidates should note:—

(a) The Mining Act and Regulations may be used at the examination but Not the Mines Regulation Act.

(b) In answering questions in Section B, reference to the appropriate Sections of the Act or to the Regulations alone will not be sufficient. Candidates must summarise the requirements of the Act and/or Regulations and should also make reference to the relevant section(s) or regulation(s).

(c) Candidates are required to pass in both sections of the paper.

SECTION A

(MINES REGULATION ACT AND REGULATIONS)

Attempt Seven (7) questions from this section

Do Not attempt more than Seven (7) questions from this section

Marks allowed are Ten (10) per question.

What is required by the Mines Regulation Act and/or Regulations regarding the following:—

1. Rises.
2. Winzes.
3. Misfires.
4. (a) Who is permitted to use explosives underground.
   (b) Safety fuse.
   (c) Re-charging holes previously fired.
5. Safety belts.
6. Ladders in shafts.
7. (a) Safety requirements when repairing shafts.
   (b) Gates to cages.
   (c) Number of men permitted to travel in a cage or skip.
8. (a) Return airways.
   (b) re-circulation of air.
   (c) Stoppings and doors.
9. (a) Crib places.
   (b) Drinking water.
   (c) Waste timber.
10. (a) Inspection of roads used by locomotives underground.
    (b) Safety provisions on locomotives.
    (c) Riding on locomotives.

SECTION B

(MINING ACT AND REGULATIONS)

Attempt Three (3) questions from this section

Marks allowed are Ten (10) per question

11. What is the maximum area of a Prospecting Area:—
    (a) Within the limits of a goldfield or mineral field.
    (b) Outside such limits.
12. (a) When must a Prospecting Area be first worked?
    (b) How long can a Prospecting Area be held?
    (c) How much gold bearing or mineral bearing material may be removed from a Prospecting Area?
13. How would you mark out and make application for a Gold Mining Lease?
14. (a) What is necessary before a miner may enter upon private land?
    (b) What is necessary before any material may be mined?
    (c) Can a Prospecting Area be held on Private Land as defined in the Act? If so, for how long?

Western Australia

Mines Regulation Act, 1946-61

Examination for Certificate of Competency as Underground Supervisor

MINING

September 1964

Time Allowed Three (3) Hours

Attempt Six (6) Questions only

Note.—Read the Examination Paper Carefully. Answers must be Written in Ink

Candidates should illustrate with sketches where possible

Note.—All questions attempted are to be answered in relation to Mining practice and are not to be confused with the Mining Law section of the examination.

1. An ore pass which has an inclination of 60 degrees to the horizontal has become "hung up". Explain fully the procedure, you as Shift Boss, would take to clear it—detail required.

2. A "dead end" leading stope 2,000 feet from the other nearest workings has been worked in a steeply dipping ore body 10 feet wide. Two-thirds of the broken ore remains to be cleaned off the level. Twelve months have elapsed since men last worked in this leading stope. The back of the stope is 20 feet above the level floor.

It is required to clean out all broken ore using a mechanical bogger.

(a) What equipment would you supply for this work?

(b) Whom would you detail to do the work?

(c) What instructions would you give?

3. Write what you know about explosives and blasting agents now used underground, the necessary precautions for safe handling and how to safely charge and blast with them.

4. Write a brief summary on the use of rock bolting as compared with stope timber.

OR

Describe two methods of timbering a level in preparation for stoping.

5. What do you know of underground ventilation, the suppression of dust and how to keep all working faces free from fumes, dust and fog.

6. Name two methods of stoping an ore body. Describe one method giving sketches to illustrate.

7. Draw a penthouse for a vertical shaft which will allow 2-ton skips to continue operating above it over a depth of 1,000 feet—Give measurements.

OR

Draw a penthouse at a depth of 2,000 feet in a underlay shaft. Two-ton skips are to operate above the penthouse—Give measurements.

OR

Draw the layout for extending an inclined adit below a working level.

8. Write a summary on the safe use of locomotives underground.

9. Two levels, one at 1,050 feet and the other at 1,200 feet have been driven on an ore body which is vertical. It is necessary to connect these two levels by either a winze or a rise.

Explain in detail how you would have this work carried out, the equipment you would use and why you chose your particular method.

10. Describe fully the steps to be taken in rescuing:—

(a) A man who has been overcome by fumes in a winze.

(b) A man who has been buried by a fall of rock.

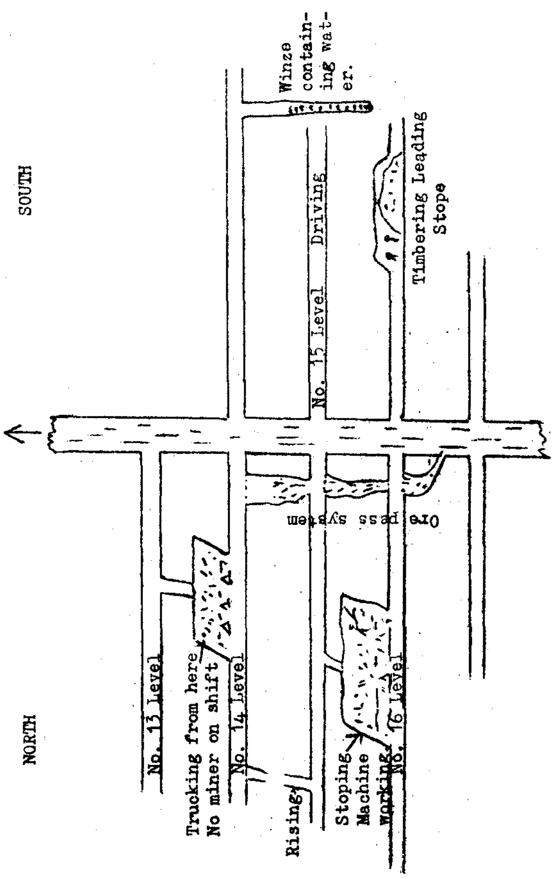
11. You are a shaft foreman and have to instruct a new platman as to his duties.

What instructions would you give him?

12. You are a Shift Boss and have 20 men under you in your section of the mine. The mine operates on both day and afternoon shift.

Work being carried out on your round and shown on the attached sketch, consists of, driving to connect with a winze which contains water, rising to a height of 40 feet, stoping, timbering a leading stope in weak ground, trucking ore from a shrink stope and hoisting ore to the surface.

Write a complete report such as you would write in your Shift Boss's report book at the end of afternoon shift on Thursday.



Western Australia.

Mines Regulation Act, 1946-61.

Examination for Certificate of Competency as Underground Supervisor.

MINING LAW.

September, 1964.

Time Allowed Two (2) Hours.

Read the Examination Paper Carefully. Answers Must be Written in Ink.

Notes:—

(i) Attempt the questions in the order given.

(ii) If you are uncertain about the answer to any question, then omit it and go on to the next.

(iii) Attempt as many questions as time permits. It is not necessary to answer all questions and Good Answers are more important than the number of questions answered.

1. State Three (3) safety requirements provided for in the above Act and Regulations for each of the following:—

(a) Winzes.

(b) Safety belts.

(c) Rises.

(d) Men travelling in skips or in cages.

2. What do the above Act and Regulations require about the following:—

(a) Hoists.

(b) Misfires.

(c) Time of blasting.

(d) Ladders in shafts.

(e) Transport of explosives underground.

(f) Men working alone.

(g) Protection of men working in a shrink stope.

(h) Repairing shafts.

(i) Employees required to know "code of signals".

(j) Stopping and doors.

(k) Ventilation of development ends.

(l) Crib places.

(m) Disused workings.

(n) Who may handle explosives underground.

(o) Re-circulation of air.

Index to State Mining Engineer's Annual Report for 1964

DIVISION III

Report of the Superintendent of State Batteries—1964

STATE AID TO MINING.

(a) *State Batteries.*

At the end of the year there were 20 State Batteries including the Northampton Base Metal Plant.

From inception to the end of 1964, gold, tin, tungsten, lead, copper and tantalite ores to the value of £18,808,355 have been treated at the State Batteries. Included in the above amount is gold premium of £7,220,360 and premium paid by sales of gold by the Gold Producers Association Ltd., of £43,480. £18,312,691 came from 3,461,354¾ tons of gold ore, £94,913 from 81,904¼ tons of tin ore, £18,850 from 3,960 tons tungsten ore, £362,985 from 31,620¾ tons lead ore, £5,966 from 220¼ tons of copper ore and £12,950 from 203¼ tons of tantalite ore.

During the year 43,966¾ tons of gold ores were crushed for 14,774 oz. bullion, estimated to contain 12,521 oz. fine gold, equal to 5 dwt. 17 grs. per ton. The average value of sands after amalgamation was 2 dwt. 23 grs. per ton, making the average head value 8 dwt. 16 grs. per ton. Cyanide plants produced 2,600 oz. fine gold, giving a total estimated production for the year of 15,121 oz. fine gold valued at £236,646.

The working expenditure for the year for all plants was £220,564 and the revenue was £39,993 giving a working loss of £180,571 which does not include depreciation or interest. Since the inception of State Batteries, the Capital expenditure has been £837,305 made up of £657,693 from General Loan Funds; £137,204 from Consolidated Revenue; £28,622 from Assistance to Gold Mining Industry; and £13,786 from Assistance to Metalliferous Mining.

Head Office expenditure including Workers Compensation Insurance and Pay Roll Tax was £28,662 compared with £22,687 for 1963.

The working expenditure from inception to the end of 1964 exceeds revenue by £2,057,821.

UNDER SECRETARY FOR MINES.

For the information of the Hon. Minister for Mines, I have the honour to submit my report on the operations of the State Batteries for the year ending 31st December, 1964.

Crushing Gold Ores.

One 20 head, five 10 head, and nine 5 head mills crushed 43,966¾ tons of ore made up of 545 separate parcels, an average of 80.67 tons per parcel. The bullion produced amounted to 14,774 oz. which is estimated to contain 12,521 oz. of fine gold, equal to 5 dwt. 17 grs. of gold per ton of ore.

The cost of crushing, including administration was 70s. 7d. per ton, a decrease of 2s. 9d. per ton compared with the previous year when 43,944¼ tons were crushed at a cost of 73s. 4d. per ton.

The average value of the ore after amalgamation, but before cyanidation was 2 dwt. 23 grs. Thus the average head value of the ore was 8 dwt. 16 grs. which is 13 grs. less than the previous years' average.

Values in this ore before cyanidation can be segregated as follows:—

	Tons	%
Over 2 dwts. 8 grs. per ton	18,288	41·6
1 dwt. 18 grs. to 2 dwts. 8 grs. per ton	4,136¾	9·4
Under 1 dwt. 18 grs. per ton	21,401	48·7
Refractory	141	·3
	43,966¾	100·0

Cyaniding.

Eight plants treated 19,709 tons of tailings from amalgamation for a production of 2,600 fine oz. of gold worth £40,691. The average content was 3 dwt. 10 grs. before cyanidation, while the residue after treatment averaged 1 dwt. 2 grs. The theoretical extraction was therefore 70 per cent. The actual extraction was 72 per cent.

The cost of cyaniding was 55s. 8d. per ton, an increase of 10d. per ton on the previous year, when 17,935 tons were treated at a cost of 54s. 10d. per ton.

Estimated Overall Recovery.

Figures for estimated recovery are:—

	Content Fine oz.	Per Ton Crushed Dwts.	Per Ton Crushed Grs.	Per cent.
Head Value	19,014	8	16	100·0
Amalgamation Recovery	12,521	5	17	65·8
Cyanidation Recovery	2,600	1	4	13·7
Total Recovery	15,121	6	21	79·5

Treatment of Ores other than Gold.

Lead Ores.

During the year the Northamption State Battery crushed 2,925¼ tons of lead ore with an estimated average content of 18.34 per cent. lead. There were 15 separate parcels, giving an average of 195 tons of ore per parcel.

A total of 646.32 tons of concentrates was produced. The concentrates averaged 75.58 per cent. lead giving an estimated content of 488.5 tons of lead in concentrates.

2,278.9 tons of tailings were discarded. These had an average content of 2.1 per cent. lead, giving a total of 47.9 tons of lead discarded in tailings.

The recovery of lead in the concentrates was 91.1 per cent. of the lead in the ore delivered to the plant.

The cost of operating the Northampton State Battery, including administration, was £10,067 3s. 7d. being 68s. 10d. per ton of ore crushed. Revenue received was £2,544 9s. being 17s. 5d. per ton. The corresponding figures for 1962 when 1,220¾ tons of ore were crushed, were, operating cost £7,131 9s. 9d., 110s. 6d. per ton, and revenue £1,428 18s., 22s. 2d. per ton. There was no lead ore treated in 1963.

Sales of lead concentrates from the Northampton State Battery for the year were valued at £61,234.

Tin Ore.—The Cue Battery crushed 10¼ tons of ore for 5 dwt. of concentrates valued at £120.

Tantalite Ore.—During the year the Cue Battery crushed 108¼ ton of ore for 10 cwt. of concentrates valued at £950.

Agriculture Copper Ore.—No treatment for the year.

Value of Production.

The estimated value of production from the State Batteries since their inception, excluding the value of gold tax paid to the Commonwealth, is:—

GOLD

	1964	Grand Total
Par Production—	£	£
Crushing	53,185	8,865,236
Cyanidation	11,108	2,183,615
Gold Premium—		
Crushing	1,242,453	5,647,492
Cyanidation	29,582	1,572,868
Open Market Premium—		
Crushing	263	32,725
Cyanidation	55	10,755
Total Gold Production	£236,646	£18,312,691

OTHER ORES REALISED

Tin—		
Ores	120	94,341
Residues	*Nil*	572
Tungsten Concentrates	*Nil*	18,850
Agricultural Copper Ore	*Nil*	5,966
Lead Concentrates	61,234	362,985
Tantalite Concentrates	950	12,950
Total Other Ores	£62,304	£495,664
Grand Total	£298,950	£18,808,355

Financial.

—	Tons	Expenditure	Receipts	Loss
		£	£	£
Crushing (Gold Mills)	44,085¼	155,653	20,382	135,271
Crushing (Northampton)	2,925¼	10,067	2,544	7,523
Cyaniding	19,709	54,844	17,067	37,777
	....	£220,564	£39,993	£180,571

The loss of £180,571 is an increase of £1,507 on the previous year. It does not include depreciation and interest on capital.

Capital Expenditure, all from General Loan Fund, was incurred as below:—

		£	s.	d.
Boogardie	Renewal of Electrical Wiring	374	5	10
Coolgardie	Cyanide Plant	936	10	5
Kalgoorlie	Rock Drill, Post Hole Digger (Sundry Expenses—Main Items paid in 1963)	17	3	7
Marble Bar	Renewal of Electrical Wiring	321	6	3
Norseman	Cyanide Plant	5,100	4	8
Northampton	2 Wilfley Tables	200	0	0
Ora Banda	Cyanide Plant and Crude Ore Bins	15,199	10	6
Tip Truck	Bedford 4 ton Tip Body	1,726	12	6
		£23,875	13	9

Cartage Subsidies.

	Tons	Cost
Ore carted to State Plants	14,160	£7,214

Comparative figures for the last three years are:—

Year	Tons Crushed	State Plants			Private Plants		Total Cost
		Tons Subsidised	Per cent. Subsidised	Cost	Tons Subsidised	Cost	
				£		£	£
1962	48,153¾	17,639	36·6	9,334	*Nil*	*Nil*	9,334
1963	44,044¼	11,681½	26·5	6,171	24	5	6,176
1964	47,010½	14,160	30·1	7,214	*Nil*	*Nil*	7,214

Administrative.

Expenditure amounted to £28,662 5s. 7d. equivalent to 8s. 7d. per ton of ore crushed and cyanided, compared with an expenditure of £22,686 13s. 4d., 7s. 2d. per ton, for 1963.

	1963			1964		
	£	s.	d.	£	s.	d.
Salaries	13,788	9	5	18,408	6	10
Pay Roll Tax	3,402	6	11	3,517	13	8
Workers' Compensation	3,805	16	3	3,506	1	10
Travelling and Inspection	725	0	11	1,870	11	8
Sundries	964	19	10	1,359	11	7
	£22,686	13	4	£28,662	5	7

Staff.

After nearly 18 years service as a Battery Manager, E. J. Sturman retired in December, 1964. He has efficiently managed many of the gold batteries, and for the last eight years has most capably managed the lead plant at Northampton.

G. McNamara was appointed Manager of the Ora Banda Battery.

Manager Sanfead was transferred from Marble Bar to Northampton.

Manager Marr was transferred from Menzies to Marble Bar.

General.

The tonnage of gold ore crushed was slightly higher than in 1963 but the average grade of ore was lower. Milling costs decreased by 2s. 9d. per ton. Operations at the Ora Banda State Battery were mainly responsible for the maintained tonnage lower grade and reduced costs, as a big tonnage of low grade easily crushed ore was treated at that plant.

Cyanide plants treated 1,774 tons of tailings more than in 1963. Recoveries were considerably higher, but costs rose by 10 pence per ton. Two new scraper-hauler plants at Norseman and Ora Banda, were completed during the year.

As expected, there was increased production of lead ore at Northampton. During the last few months of the year the Northampton Battery crushed between 600 and 700 tons per month, and it is expected to crush at that rate for at least the early months of 1965.

K. M. PATERSON,
Superintendent of State Batteries.

SCHEDULE No. 1.

Return showing tons crushed, Gold Yield by Amalgamation, Average per ton in shillings, and Total value without Premium for the year ended 31st December, 1964.

Battery	Tons Crushed	Gold Yield Bullion	Value per Ton in Shillings	Total Value without Premium
		oz.		£
Boogardie	378·25	240·50	45·78	865·80
Coolgardie	4,253·00	1,424·30	24·11	5,127·48
Cue	1,395·00	465·05	24·00	1,674·18
Kalgoorlie	9,429·25	3,965·00	30·28	14,274·00
Lake Darlot	2,882·50	1,110·45	27·74	3,997·62
Leonora	827·50	223·15	19·42	803·34
Marble Bar	1,252·00	486·00	27·95	1,749·60
Marvel Loch	3,545·25	966·65	19·63	3,479·94
Meekatharra	3,254·00	861·50	19·06	3,101·40
Menzies	3,412·50	953·95	20·13	3,434·22
Norseman	729·00	438·75	43·33	1,579·50
Nullagine	170·00	27·55	11·67	99·18
Ora Banda	10,265·00	1,944·05	13·64	6,998·58
Sandstone	168·50	110·50	47·22	397·80
Yarri	2,005·00	1,556·10	55·88	5,601·96
Total	43,966·75	14,773·50	24·19	53,184·60

SCHEDULE No. 2.

Number of Parcels Treated, Tons Crushed and Head Value for the year ended 31st December, 1964.

No. of Parcels Treated	Battery	Tons Crushed	Yield by Amalgamation Bullion		Yield by Amalgamation Fine Gold		Tailings Gross at 100%		Total Contents of Ore Fine Gold		Average per Ton Fine Gold		Gross Value per Ton Fine Gold at £4 4s. 11½d. per Ounce
			oz.	dwts.	oz.	dwts.	oz.	dwts.	oz.	dwts.	dwts.	grs.	£ s. d.
9	Boogardie	378¼	240	10	203	16	52	18	256	14	13	14	2 17 9
97	Coolgardie	4,253	1,424	6	1,207	2	675	8	1,882	10	8	20	1 17 6
19	Cue	1,395	465	1	394	3	545	9	939	12	13	11	2 17 2
108	Kalgoorlie	9,429¼	3,965	....	3,360	7	1,441	15	4,802	2	10	4	2 3 2
38	Lake Darlot	2,882½	1,110	9	941	2	680	3	1,621	5	11	6	2 7 10
19	Leonora	827½	223	3	189	2	107	12	296	14	7	4	1 10 5
17	Marble Bar	1,252	486	....	411	18	287	8	699	6	11	4	2. 7 5
51	Marvel Loch	3,545¼	966	13	819	5	625	10	1,444	15	8	4	1 14 8
30	Meekatharra	3,254	861	10	730	2	524	12	1,254	14	7	17	1 12 9
45	Menzies	3,412½	953	19	808	9	349	12	1,158	1	6	19	1 8 10
22	Norseman	729	438	15	371	17	53	2	424	19	11	16	2 9 7
5	Nullagine	170	27	11	23	7	11	18	35	5	4	4	17 9
61	Ora Banda	10,265	1,944	1	1,647	12	957	9	2,605	1	5	2	1 1 7
5	Sandstone	168½	110	10	93	13	31	15	125	8	14	21	3 3 2
19	Yarri	2,005	1,556	2	1,318	16	149	4	1,468	....	14	6	3 0 7
545		43,966¾	14,773	10	12,520	11	6,493	15	19,014	6	8	16	1 16 10

Average Tons per Parcel .... 80·67
Average Yield by Amalgamation per ton (Fine Gold) .... 5 dwts. 17 grs.
Average Head Value of Tailings per ton (Fine Gold) .... 2 dwts. 23 grs.

Schedule No. 3.

Segregation of Tailings Produced According to Value, year ended 31st December, 1964.

Battery	Payable			2 dwts. 8 gr. to 1 dwt. 18 gr.			1 dwt. 18 gr. and under			Refractory			Total		
	tons	oz.	dwts.	tons	oz.	dwts.	tons	oz.	dwts.	tons	oz.	dwts.	tons	oz.	dwts.
Boogardie	160	36	2	109	10	14	109¼	6	2	....	....	....	378¼	52	18
Coolgardie	2,518	542	13	493	53	9	1,101	51	15	141	27	11	4,253	675	8
Cue	1,294¾	536	8	68¼	7	2	32	1	19	....	....	....	1,395	545	9
Kalgoorlie	5,014¾	1,183	16	261½	25	16	4,153	232	3	....	....	....	9,429¼	1,441	15
Lake Darlot	1,458	552	19	800½	86	9	624	40	15	....	....	....	2,882½	680	3
Leonora	332½	76	7	59	5	10	436	25	15	....	....	....	827½	107	12
Marble Bar	762½	259	15	....	....	....	489½	27	13	....	....	....	1,252	287	8
Marvel Loch	2,257	553	11	40	3	18	1,248¼	68	1	....	....	....	3,545¼	625	10
Meekatharra	1,626	353	15	1,628	170	17	....	....	....	....	....	....	3,254	524	12
Menzies	946½	215	14	350	32	7	2,116	101	11	....	....	....	3,412½	349	12
Norseman	83	20	4	32½	3	8	613½	29	10	....	....	....	729	53	2
Nullagine	23	7	4	....	....	....	147	4	14	....	....	....	170	11	18
Ora Banda	1,401½	666	13	197	19	5	8,666½	271	11	....	....	....	10,265	957	9
Sandstone	159½	30	17	9	....	18	....	....	....	....	....	....	168½	31	15
Yarri	251	34	1	89	9	15	1,665	105	8	....	....	....	2,005	149	4
Total Gold	18,288	5,069	19	4,136¾	429	8	21,401	966	17	141	27	11	43,966¾	6,493	15

SCHEDULE No. 4.

Details of Extraction Tailings Treatment, 1964.

Battery	Tons Treated	Head Value		Contents	Tail Value		Contents	Recovery	Call	Recovery	Shortage	Surplus
		dwts.	grs.	dwts.	dwts.	grs.	dwts.	%	£ s. d.	£ s. d.	£ s. d.	£ s. d.
Bamboo Creek	....	....	....	....	....	....	....	....	....	29 1 8	....	29 1 8
Coolgardie	3,250	2	19	9,126	....	16	2,224	76	1,465 16 11	1,496 18 1	....	31 1 2
Kalgoorlie	4,350	3	3	14,011	....	19	3,476	75	2,237 11 7	2,264 10 11	....	26 19 4
Marble Bar	2,697	4	9	11,817	1	23	5,294	55	1,385 9 8	1,399 17 9	....	14 8 1
Marvel Loch	3,126	4	14	14,322	1	4	3,654	74	2,265 16 10	2,271 15 6	....	5 18 8
Meekatharra	3,971	3	19	15,004	1	4	4,664	69	2,195 12 1	2,347 0 9	....	151 8 8
Menzies	575	3	20	2,195	1	....	572	74	344 14 5	373 0 5	....	28 6 0
Norseman	1,440	2	21	4,160	....	22	1,302	69	606 18 4	637 12 6	....	30 14 2
Ora Banda	300	6	1	1,816	1	12	453	75	289 7 10	288 10 7	17 3	....
Total	19,709	3	10	72,451	1	2	21,639	70	10,791 7 8	11,108 8 2	17 3	317 17 9

Net Surplus	£317 0s. 6d.
Head Value	3 dwts. 10 gr.
Tail Value	1 dwt. 2 gr.
Theoretical Recovery	70 per cent.
Actual Recovery	72 per cent.

SCHEDULE No. 5.

Direct Purchase of Tailings.
Year ended 31st December, 1964.

Battery	Tons of Tailings Purchased	Amount Paid at £4 4s. 11½d. per oz.	Amount Paid Account of Premium
		£ s. d.	£ s. d.
Boogardie	19·00	6 16 1	15 12 5
Coolgardie	2,441·50	921 8 5	2,370 7 0
Cue	1,079·50	891 17 10	2,047 10 2
Kalgoorlie	4,106·75	1,659 1 8	4,123 0 4
Lake Darlot	1,219·00	1,046 0 6	2,401 6 4
Leonora	46·25	47 13 1	109 7 11
Marble Bar	734·75	229 12 6	742 17 4
Marvel Loch	2,067·50	867 17 8	2,365 16 7
Meekatharra	1,409·50	373 9 9	1,436 14 1
Menzies	672·50	275 17 9	662 14 10
Norseman	130·50	24 5 6	119 2 2
Nullagine	74·75	24 5 3	55 14 0
Ora Banda	1,173·75	1,302 16 7	3,065 16 3
Sandstone	143·50	35 1 3	80 9 11
Yarri	57·50	8 19 11	20 13 0
Total	15,376·25	7,715 3 9	19,617 2 4

SCHEDULE No. 6.

Cyanide Yield, 1964.

Battery	Tons	Fine oz.	Value	Premium	Total
			£	£	£
Bamboo Creek	....	6·78	29·083	77·171	106·254
Coolgardie	3,250	352·36	1,496·903	4,008·741	5,505·644
Kalgoorlie	4,350	528·87	2,264·545	6,017·011	8,281·556
Marble Bar	2,697	324·92	1,399·888	3,696·721	5,096·609
Marvel Loch	3,126	534·82	2,271·777	6,084·804	8,356·581
Meekatharra	3,971	552·56	2,347·035	6,286·373	8,633·408
Menzies	575	82·18	373·021	934·975	1,307·996
Norseman	1,440	149·89	637·625	1,705·279	2,342·904
Ora Banda	300	67·78	288·529	771·138	1,059·667
Total	19,709	2,600·16	11,108·406	29,582·213	40,690·619

SCHEDULE No. 7.

Statement of Receipts and Expenditure for the year ended 31st December, 1964.

Milling.

Battery	Tons Crushed	Management and Supervision	Wages	Stores	Total Working Expenditure	Cost per Ton	Repairs and Renewals	Sundries	Gross Expenditure	Cost per Ton	Receipts	Receipts per Ton	Profit	Loss
		£ s. d.	£ s. d.	£ s. d.	£ s. d.	s. d.	£ s. d.	£ s. d.	£ s. d.	s. d.	£ s. d.	s. d.	£ s. d.	£ s. d.
Boogardie	378¼	593 3 9	997 10 7	408 11 4	1,999 5 8	105 9	230 0 7	424 17 1	2,654 3 4	140 4	151 1 4	8 0	....	2,503 2 0
Coolgardie	4,253	2,844 6 11	4,178 10 9	2,346 3 0	9,369 0 8	44 1	2,898 12 0	2,007 10 8	14,275 3 4	67 2	1,718 6 9	8 1	....	12,556 16 7
Cue	1,513½	2,385 11 10	1,789 19 3	1,427 8 6	5,602 19 7	74 0	1,818 16 11	1,234 6 0	8,656 2 6	114 5	622 13 5	8 3	....	8,033 9 1
Kalgoorlie	9,429¼	5,060 12 4	7,235 11 11	6,153 2 6	18,449 6 9	39 1	4,618 13 8	4,532 1 11	27,600 2 4	58 7	5,266 11 10	11 2	....	22,333 10 6
Lake Darlot	2,882½	3,119 8 10	4,354 19 2	1,379 12 9	8,854 0 9	61 5	1,254 5 3	1,908 8 2	12,016 14 2	83 5	1,432 7 4	9 11	....	10,584 6 10
Laverton	....	....	138 0 0	....	138 0 0	....	3 11 10	53 7 5	194 19 3	....	122 6 10	....	....	72 12 5
Leonora	827½	779 0 5	1,423 5 6	693 0 10	2,895 6 9	70 0	629 14 6	589 0 5	4,114 1 8	99 5	430 6 3	10 5	....	3,683 15 5
Marble Bar	1,252	4,378 5 2	1,324 5 10	1,614 13 0	7,317 4 0	116 10	3,850 16 8	851 4 10	12,019 5 6	192 0	676 1 11	10 10	....	11,343 3 7
Marvel Loch	3,545¼	1,956 12 5	5,922 13 11	1,682 12 1	9,561 18 5	53 10	1,149 8 5	1,679 14 0	12,391 0 10	69 11	1,958 1 1	11 1	....	10,432 19 9
Meekatharra	3,254	2,019 15 0	5,285 11 1	1,568 6 6	8,873 12 7	54 6	2,164 1 11	1,857 7 11	12,895 2 5	79 3	1,547 7 11	9 6	....	11,347 14 6
Menzies	3,412½	2,381 2 2	3,351 4 1	1,296 0 11	7,028 7 2	41 2	1,054 1 10	2,019 17 6	10,102 6 6	59 3	1,550 14 2	9 1	....	8,551 12 4
Norseman	729	954 16 11	1,287 10 5	749 3 2	2,991 10 6	82 1	873 2 7	1,395 2 10	5,259 15 11	144 4	394 0 3	10 10	....	4,865 15 8
Nullagine	170	235 9 4	402 1 11	119 18 1	757 9 4	88 11	392 18 5	315 17 4	1,466 5 1	172 6	60 4 6	7 1	....	1,406 0 7
Ora Banda	10,265	3,557 8 7	6,971 7 11	3,172 9 8	13,701 6 2	26 8	3,530 14 1	4,911 17 7	22,143 17 10	43 2	3,294 17 8	6 5	....	18,849 0 2
Payne's Find	....	....	84 11 11	30 1 4	114 13 3	....	36 9 11	32 17 11	184 1 1	....	21 6 10	....	....	162 14 3
Peak Hill	....	....	240 16 10	....	240 16 10	....	20 9 5	113 1 3	374 7 6	....	....	....	....	374 7 6
Sandstone	168½	506 7 3	689 8 7	100 9 8	1,296 5 6	153 10	165 14 7	509 16 0	1,971 16 1	234 1	79 15 2	11 7	....	1,892 0 11
Yarri	2,005	1,747 4 6	2,290 18 4	1,174 6 6	5,212 9 4	52 0	995 3 8	1,126 0 1	7,333 13 1	73 2	1,037 6 10	10 4	....	6,296 6 3
Head Office	....	....	....	....	....	....	....	....	....	....	18 14 11	....	18 14 11	....
Sub-Total	44,085¼	32,519 5 5	47,968 8 0	23,915 19 10	104,403 13 3	47 4	25,686 16 3	25,562 8 11	155,652 18 5	70 7	20,382 5 0	9 3	18 14 11	135,289 8 4
Northampton	2,925¼	3,008 18 9	2,371 12 3	886 7 8	6,266 18 8	42 10	1,780 1 3	2,020 3 8	10,067 3 7	68 10	2,544 9 0	17 5	....	7,522 14 7
Total	47,010½	35,528 4 2	50,340 0 3	24,802 7 6	110,670 11 11	47 1	27,466 17 6	27,582 12 7	165,720 2 0	70 6	22,926 14 0	9 9	18 14 11	142,812 2 11
Net Loss	....	....	....	....	....	....	....	....	....	....	....	....	....	142,793 8 0

SCHEDULE No. 8.

Receipts and Expenditure, 1964.

Cyaniding.

Battery	Tons	Management and Supervision	Wages	Stores	Total Working Expenditure	Cost per Ton	Repairs and Renewals	Sundries	Gross Expenditure	Cost per Ton	Receipts	Receipts per Ton	Profit	Loss
		£ s. d.	£ s. d.	£ s. d.	£ s. d.	s. d.	£ s. d.	£ s. d.	£ s. d.	s. d.	£ s. d.	s. d.	£ s. d.	£ s. d.
Coolgardie	3,250	1,131 3 11	2,952 5 4	1,121 9 1	5,204 18 4	46 0	516 5 1	2,680 18 3	8,402 1 8	51 8	3,115 6 3	19 2	....	5,286 15 5
Kalgoorlie	4,350	2,134 17 10	3,884 17 6	3,942 8 5	9,962 3 9	45 10	886 0 6	2,302 16 5	13,151 0 8	60 6	5,868 2 0	27 0	....	7,282 18 8
Marble Bar	2,697	310 0 0	2,580 16 5	830 7 3	3,721 3 8	27 7	655 17 9	1,380 0 11	5,757 2 4	42 8	582 12 3	4 4	....	5,174 10 1
Marvel Loch	3,126	1,422 6 9	2,797 2 5	1,669 14 8	5,889 3 10	37 8	157 1 4	1,957 12 8	8,003 17 10	51 2	4,433 19 10	28 4	....	3,569 18 0
Meekatharra....	3,971	477 0 11	4,968 7 8	3,822 15 1	9,268 3 8	46 8	130 5 7	2,343 16 3	11,742 5 6	59 2	2,710 2 5	13 8	....	9,032 3 1
Menzies	575	394 9 3	1,063 13 3	506 6 3	1,964 8 9	68 4	404 0 6	485 1 1	2,853 10 4	99 3	1,016 11 2	35 5	....	1,836 19 2
Norseman	1,440	563 4 10	1,065 2 7	934 8 3	2,562 15 8	35 7	33 9 7	1,038 7 6	3,634 12 9	50 6	1,164 13 2	16 2	....	2,469 19 7
Ora Banda	300	237 4 6	337 10 3	324 18 2	899 12 11	60 0	114 6 9	285 8 4	1,299 8 0	86 7	335 9 4	22 5	....	963 18 8
Total	19,709	6,670 8 0	19,649 15 5	13,152 7 2	39,472 10 7	40 1	2,897 7 1	12,474 1 5	54,843 19 1	55 8	19,226 16 5	19 6	....	35,617 2 8

	£ s. d.		£ s. d.
Total Receipts	19,226 16 5		
Interest Paid to Treasury	2,160 0 0		2,160 0 0
	17,066 16 5	Gross Loss	37,777 2 8

STATE BATTERIES.

Trading and Profit and Loss Account.

For the year ended 31st December, 1964.

1963 £		1964 £	£
	Trading Costs—		
117,270	Wages	112,188	
35,821	Stores	37,955	
26,538	Repairs, Renewals and Battery Spares	30,364	
35,145	General Expenses and Administration	40,057	
214,774			220,564
	Earnings—		
35,710	Milling and Cyaniding Charges		39,993
179,064	Operating Loss for the Year		180,571
	Other Charges—		
26,362	Interest on Capital	27,436	
12,781	Depreciation	15,155	
2,731	Superannuation—Employers Share	2,731	
41,874			45,322
£220,938	Total Loss for the Year		£225,893

STATE BATTERIES.

Balance Sheet.

As at 31st December, 1964.

31st December, 1963 £	Funds Employed	31st December, 1964 £	£
	Capital—		
633,817	Provided from General Loan Fund	657,693	
137,204	Provided from Consolidated Revenue Fund	137,204	
771,021			794,897
	Reserves—		
28,622	Commonwealth Grant—Assistance to Goldmining Industry	28,622	
13,786	Commonwealth Grant—Assistance to Metalliferous Mining	13,786	
42,408			42,408
	Liability to Treasurer—		
1,051,330	Interest on Capital		1,078,767
10,000	Advance for Purchase of Tailings		15,000
	Other Funds—		
1,875,182	Provided from Consolidated Revenue Fund (Excess of payment over collections)		2,057,821
3,749,941			3,988,893
	Deduct—		
	Profit and Loss :		
3,316,245	Loss at Commencement of year	3,537,183	
220,938	Loss for Year	225,893	
3,537,183	Total Loss from Inception		3,763,076
£212,758			£225,817
	Employment of Funds		
	Fixed Assets—		
765,430	Plant, Buildings and Equipment	789,306	
655,687	*Less* Depreciation	670,842	
109,743			118,464
	Current Assets—		
2,210	Debtors	2,528	
84,905	Stores	85,009	
2,876	Battery Spares	4,053	
	Purchase of Tailings :		
3,045	Treasury Trust Account	3,113	
57,511	Tailings not treated	64,351	
7,740	Estimated Gold Premium	8,535	
158,287			167,589
268,030	Total Assets		286,053
	Deduct—		
	Current Liabilities :		
9,934	Creditors	9,464	
35,042	Liability to Treasurer (Superannuation—Employers Share)	37,773	
	Purchase of Tailings :		
2,556	Creditors	4,464	
7,740	Estimated Premium Due	8,535	
55,272			60,236
£212,758			£225,817

DIVISION IV

Annual Report of the Geological Survey Branch of the Mines Department for the Year 1964

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DIVISION IV

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Annual Report of the Geological Survey Branch of the Mines Department for the Year 1964

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The Under Secretary for Mines:

I submit herewith for the information of the Honourable Minister for Mines my report on the activities of the Geological Survey for the year 1964, together with some reports on investigations made for departmental purposes.

ORGANIZATION

The professional staff was at full strength until two officers resigned about mid-year. Replacements have been appointed but have not yet arrived.

The numerous requests for the services of the engineering geologists have continued, and to cope with the work required in major governmental development projects, the appointment of an additional officer to the Hydrology and Engineering Geology Division has been approved.

The use of palynology in association with the search for underground water has increased greatly and approval has been given to recruit a palynologist.

The Commonwealth Government is to provide financial assistance to the State for an accelerated programme of search for groundwater which will require the appointment of additional hydrogeologists early in 1965.

With the discovery of oil and gas at Barrow Island and Yardarino and the increased tempo of oil search in this State, the Sedimentary (Oil) Division, with only three officers, is finding it increasingly difficult to contribute to the search for oil as well as keep abreast of current developments.

STAFF

Appointments

Name	Postition	Effective Date
Professional:		
M. E. Redman, B.Sc.	Geologist, Grade 2 (Female)	1/4/64
I. R. Williams, B.Sc. (Hons.)	Geologist, Grade 2—	
	(Temporary)	3/2/64
	(Permanent)	3/8/64
R. Milbourne, B.Sc.	Geologist, Grade 2 (Temporary)	23/11/64
Clerical and General:		
S. W. H. Schellpeper	Geophysical Assistant	6/1/64
E. Grylls	Library Assistant (Female)	3/3/64
G. W. Wiltshire	Clerk	3/3/64
G. Craven	Typist (Temporary Female)	25/5/64
V. M. Marshall	Library Assistant (Female)	19/8/64
J. R. Sorensen	Laboratory Assistant	31/12/64
Promotions:		
J. L. Daniels	Geologist Grade 2 to Geologist Grade 1	31/7/64
Transfers:		
R. M. Landquist	Typist	25/5/64
Resignations:		
E. E. D'Arcy Evans	Library Assistant	3/1/64
B. Yonge	Geologist, Grade 2	20/5/64
C. Emmenegger	Geologist, Grade 2	6/8/64
E. Grylls	Library Assistant (Female)	14/8/64

ACCOMMODATION

The extension to the Dianella Store was completed and the Survey's rock and mineral collection is now housed in it, after being scattered in several stores for some years.

The survey continues to suffer from the lack of adequate and consolidated office accommodation. A warehouse is now being converted into additional office space. This will mean that the offices of this Branch are spread through five separate small buildings in three adjoining streets, with the Head Office of the Department and the Drafting Branch on the opposite side of the city.

The provision of centralized office accommodation at least for the Geological Survey Branch is overdue.

OPERATIONS

HYDROLOGY AND ENGINEERING GEOLOGY DIVISION

E. P. D. O'Driscoll (Chief Hydrogeologist), K. Berliat (Senior Geologist), F. R. Gordon (Senior Geologist), J. D. Wyatt, K. H. Morgan, A. D. Allen, E. E. Swarbrick, P. Whincup, R. Milbourne. J. R. Passmore was on leave without pay while engaged on a Water Research Foundation project.

Hydrology

Exploratory drilling in the Lake Allanooka area, completed during the year, proved substantial groundwater reserves, which are now being developed as a town water supply for Geraldton. Groundwater conditions at Wicherina were also assessed.

Five more bores were drilled near Arrino, and an extensive drilling programme is now underway as an investigation for a town water supply for Morawa. Permian fossils were found at the surface and in some bores, and the hydrogeology is more complicated than at first thought.

At Mandurah, five bores have now been drilled, and work is continuing. Usable water has been found several miles east of the town, but reserves still await proving.

Five of a programme of six deep bores extending west across the Perth Basin from Bullsbrook to the coast were drilled. A test bore was also drilled at Gingin, for town water supply purposes.

In the Gnangara Lake area the initial exploration programme of 12 bores was completed, and the existence of large volumes of good quality water was established.

The groundwater resources of part of the Kimberley area were assessed, in conjunction with the regional mapping programme.

Field work on a district survey at Albany for a town water supply was suspended because of shortage of staff. Drilling of three more production bores in the Sand Patch Area was recommended as a temporary measure.

Three test bores were drilled for the Muja Power Station at Collie. Results were disappointing, and other methods of obtaining water for the project were proposed.

Four bores were drilled to examine groundwater conditions in an area being opened for settlement in the Midlands sand plain country, and four bores were drilled near Hyden as an extension of last year's investigation.

Field surveys on Government projects were made for the towns of Northampton, Hall's Creek, Munglinup, Esperance, Derby, Kununurra, Meekatharra, Roebourne, Port Samson, Port Hedland, Nullagine, Marble Bar and Mt. Magnet; and for Albany High School, Stirling Range National Park and Bindoon Army Camp.

In conjunction with other Departments, proposals were made for the introduction of legislation to control drilling for groundwater within the State.

Engineering Geology

A diamond drilling programme of five holes at the Ord River Main Dam Site was supervised; shafts, bulldozer costeans and quarry sites were mapped; and a detailed geological map was prepared at a scale of 50 feet to an inch. Work associated with the feasibility and design stages of the dam is now complete.

The geological setting of the Secure Bay—Walcott Inlet tidal power scheme was examined during a helicopter survey. A quick reconnaissance was made of three possible dam sites on the Gascoyne and Lyons Rivers.

Advice was given at various stages during construction work at Waroona Dam on engineering problems arising from geological conditions.

Because of rock excavation characteristics, water seepages and varying slope stabilities, a considerable amount of consulting work was entailed on the Avon Valley Deviation of the Standard Gauge Railway. On the Merredin—Kalgoorlie section, reconnaissance work for water supply, quarry sites, and route details was undertaken.

Two alternative dam sites on Wungong Brook and a dam site on Gooralong Brook, were investigated for the Metropolitan Water Supply Board, to enable design to proceed. The work included diamond drilling and electric logging of bore holes. Correlation between water pressure tests and resistivity and self-potential logs proved of value, particularly in zones of core loss.

Minor geological work was also done on such projects as two proposed dam sites at Denmark, Serpentine Dam and Broome Jetty.

SEDIMENTARY (OIL) DIVISION

P. E. Playford (Supervising Geologist), G. H. Low and D. C. Lowry.

The progress of oil exploration in Western Australia was followed closely during the year, and the work programmes of oil exploration companies were reviewed. These matters occupied considerably more of the Division's time than in previous years owing to the increase in the rate of oil exploration in this State and the discovery of oil and gas at Yardarino and Barrow Island.

Field work during the year was conducted in the Perth, Canning and Officer Basins. In the Perth Basin field mapping was completed as far north as the Moore River and it will be extended further north during 1965. In the Canning Basin the detailed mapping of the Lennard Shelf reef complexes was completed, and the preparation of a bulletin on this project was commenced. A short reconnaissance field trip was made in April through the northern part of the Officer Basin in conjunction with an expedition by the Department of Native Welfare.

In the Gingin—Dandaragan area the drilling project to evaluate the Cretaceous glauconite deposits was completed. This project, started in 1963, was designed to assist the C.S.I.R.O. in the possible development of a process to extract potash from glauconite.

A core-drilling programme of 17 boreholes in the Collie area was supervised on behalf of the State Electricity Commission. The results assisted in the further evaluation of the structure and coal reserves of the Muja Depression.

REGIONAL GEOLOGY DIVISION

R. C. Horwitz (Supervising Geologist), J. Sofoulis (Senior Geologist), J. L. Daniels, M. J. B. Kriewaldt, I. Gemuts, I. R. Williams.

Eastern Goldfields Area

Field work was commenced on the Kalgoorlie 1:250,000 Sheet; one half of this area is now mapped. Information was supplied to residents and mining companies on hydrology, mineral resources and general geology. Field work was carried out and reports were written on ground water investigations for pastoralists in the Kanowna region, and on the general geology between Kalgoorlie and Koolyanobbing for the Engineering Geology section.

Pilbara Area

Field work was completed on the Yarraloola and Wyloo 1:250,000 Sheets. Information was supplied to prospectors and mining companies on mineral resources and general geology.

Kimberley Area

In conjunction with the Bureau of Mineral Resources, the programme of geological mapping, commenced in 1962, was continued; field work was completed on Lansdowne and Mount Ramsay 1:250,000 Sheets.

Mapping was done and a report was written on the geology of the Ord River Main Dam Site area.

General

Examinations of the Blackstone Range and the Warburton Range were made. Papers were given to the Australasian Institute of Mining and Metallurgy Congress in Kalgoorlie and Perth on problems pertaining to regional geology in Western Australia. Samples were selected, throughout this State, for a joint programme of rock age determination with members of the Australian National University, in Canberra.

MINERAL RESOURCES DIVISION

W. N. MacLeod (Supervising Geologist), L. E. de la Hunty (Senior Geologist), G. R. Ryan and R. Halligan.

A comprehensive survey of the blue asbestos resources of the Hamersley Range area was commenced during 1964. This work had been scheduled for 1965, but was commenced this year to assist Australian Blue Asbestos Pty. Ltd., who are currently engaged in a protracted drilling programme to establish ore reserves in the Wittenoom Gorge area. This survey is a major project and is expected to be continued by two geologists for the next two years.

Manganese deposits at Woodie Woodie and Mt. Sydney were drilled to test their extension in depth.

A mineral appraisal of the Mt. Ramsay and Lennard River 1:250,000 Sheet areas in the Kimberley area was made, in conjunction with the regional mapping programme.

Other investigations included an examination of vermiculite deposits at Young River, Eucla Division; mapping and examination of the new level which was opened up at the Comet Mine at the Pinnacles, near Cue; and examination and sampling of gold prospects near Lake Grace. An initial examination of deposits of glass sands near Gnangara Lake was made, and advice and information given to numerous interested companies and individuals on other industrial minerals in the Perth area.

COMMON SERVICES DIVISION

Petrology (A. F. Trendall)

Sixteen file reports and one Record were written, describing rock collections containing between one and 60 specimens, and including material supplied by all Divisions of the Survey and by the public. In addition, two papers were prepared for publication externally. A total of 1,335 thin sections and 23 polished mounts were prepared in the laboratory.

Geologists from the field parties are encouraged to carry out petrological work in consultation with the Petrologist. Conversely, the Petrologist spent eight weeks in the field: in the Kalgoorlie, Ashburton, Pilbara and Kimberley areas.

Apart from the examination of collections on behalf of the field parties, two special studies occupied much attention: the banded iron formations of the Hamersley Range and what might be called the "isotope petrology" of the Pilbara area. The first of these arises from the recent recovery of a series of diamond drill cores through the Brockman Iron Formation in the Wittenoom Gorge area. The cores constitute a sample of unoxidised, unmetamorphosed, and undisturbed banded iron formation, which is unique in the world and which should give correspondingly valuable information concerning the origin of these rocks and their contained asbestos. The second study involved the collection and examination of over 200 rocks as part of a joint project with the Australian National University to determine the ages, by radiometric methods, of the rock types and stratigraphic successions in the Pilbara area.

Studies which occupied little time but which possessed particular interest were an investigation for the Western Australian Museum of rock weathering over aboriginal engravings and an examination of enigmatic lumps of fused glass which are widely distributed in soil over the southern part of the State. The glass has often been miscalled "slag" in the past but is now known to have a natural origin; whether this is soil fusion by bush fires or lightning has yet to be resolved.

Palaeontology (H. S. Edgell)

The wide range of material submitted during 1964 included fossils, pseudofossils and fossiliferous sediments of ages ranging from Precambrian to Quaternary. Fifty-seven file reports and two Records were written. A bulletin on certain palaeontological groups from the Lennard Shelf reef complexes of the Canning Basin is in preparation.

As in 1963, the majority of requests for palaeontological advice were in the field of palynology. Cores and cuttings from some 56 bores drilled for water, oil and stratigraphic information were examined. Requests for identification of the formation, facies and geological age of most of these samples were made by the Hydrology Division. The more detailed microplankton zonation of the Cretaceous sequence established in 1963, proved useful in stratigraphic correlation of many water bores in the Perth Basin.

Cores from the petroliferous interval in Barrow No. 1 Well were submitted by West Australian Petroleum Pty. Ltd. for identification of the stratigraphic level encountered. Surface and shallow subsurface samples, including megafossils, from the Officer Basin were examined at the request of Hunt Oil Co.

In the field of micropalaeontology, the identification of numerous foraminifera belonging to the endothyrid and tournayellid groups proved useful in stratigraphic studies of the Lennard Shelf reef complexes by the Sedimentary Division. Conodonts were separated by advanced laboratory techniques from stratigraphically important samples from this area. Algae and early coelenterates known as stromatoporoids were also studied in detail as they were major reef-building organisms in the Devonian of the northern part of the Canning Basin.

Research is being continued into the identification of calcareous algae and their use for stratigraphic correlation of Late Precambrian rocks. A preliminary study on calcareous algae and probable medusoids from the Hamersley Range was completed and a paper prepared for publication externally.

Geophysics (D. L. Rowston)

Geophysical activity was centred mainly on various types of investigations for the Hydrology and Engineering Geology Division, and among these well-logging operations predominated. Twenty-two water bores, one coal bore and four diamond drill holes were logged with the Widco Well-logger the results were used for geological correlations and water salinity determinations. The latter were not entirely satisfactory, and a study to establish reliable methods of calculating salinities from the potential and resistivity logs is being continued. Further experimental resistivity work to assist groundwater search was carried out in the Kalgoorlie region.

Two metalliferous surveys were made to test the effectiveness of geophysical prospecting methods. A gravity survey over some manganese deposits in the Mt. Sydney—Woodie Woodie area showed that the gravimeter can detect manganese deposits of reasonable size, and can give a preliminary assessment of concealed ore bodies prior to drilling. The other test survey, at Thaduna in the Peak Hill Goldfield, indicated that electromagnetic methods can delineate the shears and faults with which copper mineralisation in the area is associated.

Technical Information Section (R. R. Connolly and M. E. Redman)

Technical editing of reports, maps and plans continued to be the major function of this section. During the year, 36 Records were prepared for issue and a number of reports and maps were edited for publication.

The library development continued with the re-arrangement of books and serial publications. Cataloguing was revised to include locality and subject indexes as well as those for author and mineral. The aerial photograph library was expanded and photo-mosaics and flight diagrams were indexed and reorganised.

The Survey's rock and mineral collection was integrated at the Dianella Store. The sludge sample collection was sorted, and many samples were re-bagged to ensure their preservation.

In conjunction with the Western Australian Museum a geological display was exhibited at the Wild Life Show and an International Exhibit of Hydrogeological Maps was arranged for public display. Many requests from schools, prospectors and others for mineral and rock specimens received attention.

Considerable time was spent in answering oral and written enquiries from the general public.

ACTIVITIES OF THE COMMONWEALTH BUREAU OF MINERAL RESOURCES

The Bureau of Mineral Resources carried out both geological and geophysical work within the State during the year. The following projects were undertaken:

(1) Regional mapping of the Mt. Ramsay and Lansdowne 1 : 250,000 Sheets in the Kimberley area, jointly with the Geological Survey of Western Australia.

(2) Continuation of sampling of Precambrian rocks in the Kimberley area for age determination studies.

(3) Low-level aeromagnetic survey (Cessna aircraft) of small selected areas near Kalgoorlie and Norseman.

(4) Aeromagnetic survey (DC3 aircraft) of the Menzies and Leonora 1 : 250,000 Sheet areas.

(5) Regional seismic lines across the central Perth Basin near Bullsbrook and across the southern part of the Carnarvon Basin.

PROGRAMME FOR 1965

HYDROLOGY AND ENGINEERING GEOLOGY DIVISION

Hydrology

(i) Continuation of the hydrogeological survey of the Perth Basin, including deep drilling.

(ii) Hydrogeological investigation and/or exploratory drilling for underground water supplies in the following areas: Mandurah, Gnangara Lake, Arrowsmith River (for Morawa town water supply), Albany, Esperance, Mullewa, Yericoin, Hopetoun and Port Hedland.

(iii) Hydrological assistance to pastoralists in the Kimberley area:

- (a) Bore site selection as required by pastoralists.
- (b) Regional hydrogeological mapping in conjunction with the Bureau of Mineral Resources.

(iv) Miscellaneous investigations as required.

Engineering Geology

(i) Review of investigation for contract purposes: Ord River Main Dam Site.

(ii) Supervision of drilling and geological investigation: Dimond Gorge Dam Site.

(iii) Investigation of dam sites for Public Works Department: Gascoyne River, Harvey and Denmark.

(iv) Investigation of dam sites for Metropolitan Water Supply Board: Wungong Brook, Dandalup Brook and Victoria Reservoir.

(v) Standard Gauge Railway:

- (a) Assessment of Koolyanobbing/Kalgoorlie Section.
- (b) Investigation of quarry sites, Merredin to Kalgoorlie.
- (c) Investigation and advice on railway cuttings.

(vi) Miscellaneous investigations as required.

SEDIMENTARY (OIL) DIVISION

(i) Active interest in the progress of oil exploration in Western Australia.

(ii) Continuation of the mapping programme in the Perth Basin.

(iii) Completion of the study of the Lennard Shelf area, Canning Basin.

(iv) Commencement of a geological survey of the Eucla Basin.

(v) Miscellaneous investigations as required.

REGIONAL GEOLOGY DIVISION

(i) Continuation of regional mapping on the Edmund 1 : 250,000 Sheet in the North-West Division.

(ii) Continuation of regional mapping on the Kalgoorlie 1 : 250,000 Sheet in the Eastern Goldfields area.

(iii) Continuation of regional mapping in the Kimberley area, in conjunction with the Bureau of Mineral Resources.

(iv) Commencement of regional mapping on the Cooper and Scott 1 : 250,000 Sheets in the Eastern Division.

(v) Revision of the Geological Map of Western Australia.

MINERAL RESOURCES DIVISION

(i) Completion of regional mapping and mineral investigation of the Robertson 1 : 250,000 Sheet.

(ii) Continuation of the regional investigation of the blue asbestos deposits of the Hamersley Range.

(iii) Investigation of mineral occurrences in the Kimberley area in conjunction with regional mapping by the Bureau of Mineral Resources.

(iv) Investigation of the pegmatites of the Yalgoo and Murchison Goldfields.

(v) Investigation of the nickel occurrences at Wingellina.

(vi) Miscellaneous investigations as required.

PUBLICATIONS AND RECORDS

During 1964, the first three 1:250,000 Geological Maps with Explanatory Notes compiled by this Survey were issued. One was printed by the Government Printer and two were published by the Bureau of Mineral Resources for the Mines Department. No bulletins were issued.

Thirty-six Records were prepared and issued.

Issued During 1964

Annual Report for 1962.

Geological Map of Boorabbin 1 : 250,000 Sheet (SH/51-13 International Grid) with Explanatory Notes.

Geological Map of Balfour Downs 1 : 250,000 Sheet (SF/51-9 International Grid) with Explanatory Notes.

Geological Map of Dampier and Barrow Island 1 : 250,000 Sheets (SF/50-2 and SF/50-1 International Grid) with Explanatory Notes.

In Press

Annual Report for 1963.

Geological Map of Mt. Bruce 1 : 250,000 Sheet (SF/50-11 International Grid) with Explanatory Notes.

In Preparation

The following 1 : 250,000 Geological Maps with Explanatory Notes are being prepared, the field work for each having been completed: Port Hedland, Roy Hill, Newman, Roebourne, Pyramid, Turee Creek, Yarraloola, Wyloo, Widgiemooltha, Augusta and Busselton.

Bulletin—The Hamersley Iron Province.

Bulletin—Devonian Reef Complexes of the Lennard Shelf, Canning Basin.

Bulletin—Palaeontology of the Lennard Shelf, Canning Basin.

Records Produced

No.	Author(s)	Title
1964/1	A. D. Allen	Report on drilling at Billeranga Hills for the Morawa Town Water Supply.
1964/2	J. R. Passmore	Hydrogeology of the Cambridge Gulf, Lissadell and Dixon Range 4-mile Sheets, East Kimberleys, W.A.
1964/3	K. H. Morgan	Groundwater Resources of the Coastal Sand Dune Area, Lancelin Township, W.A.
1964/4	F. R. Gordon	Ord River Main Dam Site No. 2, Rockfill Dam Proposal. Investigations—1963.
1964/5	L. E. de la Hunty	Explanatory Notes on the Mt. Bruce 1 : 250,000 Geological Sheet, Western Australia.
1964/6	F. R. Gordon	Secure Bay—Walcott Inlet Tidal Power Scheme, Preliminary Geological Report.
1964/7	W. N. MacLeod	Report on the Vermiculite Deposits, Young River, Eucla Division.
1964/8	W. N. MacLeod	Gold Mineralization in the Vicinity of Griffins Find, Lake Grace Area, South West Division. *(Restricted.)*
1964/9	W. N. MacLeod	Iron Ore Deposits in the Eastern Section of the Hamersley Iron Province.
1964/10	P. E. Playford	Report on Native Welfare Expedition to the Gibson and Great Sandy Deserts, April, 1964.
1964/11	G. R. Ryan	Explanatory Notes on the Roebourne 1 : 250,000 Geological Sheet.
1964/12	A. F. Trendall	Slaggy Siliceous Glass Occurring Naturally on the Surface at Various Localities in the Southern Part of Western Australia.
1964/13	H. S. Edgell	Lower Cretaceous Fossils from Outcrops of the Wilkinson Range Beds, Officer Basin. *(Restricted)*
1964/14	B. Yonge	Groundwater Investigations in a Part of the Darling Range East of Perth.
1964/15	C. Emmenegger	Report on Exploratory Drilling for Underground Water at Mandurah—Perth Basin, W.A.
1964/16	D. L. Rowston	Geophysical Investigations at Thaduna, W.A., June, 1964. *(Restricted)*
1964/17	K. H. Morgan	Hydrogeology of the Southern Part of the Gnangara Lake Area, South-West Division, Western Australia.
1964/18	R. C. Horwitz	The Geology of the Region Surrounding the Ord River Main Dam Site, Western Australia.
1964/19	H. S. Edgell	Micropalaeontology and Stratigraphy of Core Samples from Barrow No. 1 Well, Carnarvon Basin, W.A. *(Restricted)*
1964/20	W. N. MacLeod & L. E. de la Hunty	Explanatory Notes on the Roy Hill 1: 250,000 Geological Sheet.
1964/21	K. Berliat	Report on Drilling for Underground Water, Watheroo Town Supply.

No.	Author(s)	Title
1964/22	F. R. Gordon	Dimond Gorge Dam Site, Geological Reconnaissance Investigation, 1962.
1964/23	E. E. Swarbrick	Geology and Hydrology of the Wicherina Area, W.A.
1964/24	F. R. Gordon	Kennedy Range Dam Site, Gascoyne River, a Preliminary Appraisal.
1964/25	D. L. Rowston	Pilbara Manganese Deposits, W.A.—Gravity Survey, 1964.
1964/26	F. R. Gordon	Broome Jetty Foundation Investigations.
1964/27	F. R. Gordon & J. D. Wyatt	Engineering Geology of the Jarrahdale Dam Site.
1964/28	W. N. MacLeod ..	The Comet Mine, Pinnacles Group near Cue, G.M.L. 670D and 676D. *(Restricted)*
1964/29	J. Sofoulis	Geological Reconnaissance of Proposed Route between Koolyanobbing and Kalgoorlie—W.A.G.R. Standard Gauge Railway.
1964/30	G. H. Low	Coal Drilling in the Muja Formation near Collie.
1964/31	F. R. Gordon	Ballast Quarry Sites between Merredin and Koolyanobbing, Standard Gauge Railway.
1964/32	L. E. de la Hunty	Report on Investigation of Manganese Deposits in the Mt. Sydney—Woodie Woodie Area, Pilbara Goldfield.
1964/33	L. E. de la Hunty	Glass Sands at Gnangara Lake.
1964/34	R. Halligan	The Narlarla Lead-Zinc Deposits, Barker River Area, West Kimberley District. *(Restricted)*
1964/35	P. E. Playford & D. C. Lowry	Wells Drilled for Petroleum Exploration in Western Australia to the end of 1964.
1964/36		Provisional Subdivisions of the Precambrian, Western Australia.

12th March, 1965.

J. H. LORD,
Director.

GROUNDWATER PROSPECTS FOR ESPERANCE TOWN WATER SUPPLY

by

E. P. D. O'Driscoll

INTRODUCTION

The population of the town of Esperance is rapidly expanding, and future water supply requirements are estimated at 20,000 gallons per hour, with an annual consumption of 80 million gallons. This is considerably more than is available from existing bores, but an inspection of the area indicates that substantial reserves exist, and are as yet undeveloped.

Esperance is on the south coast about 350 miles east-southeast of Perth, and lies in a narrow 25-inch rainfall belt, the rainfall decreasing quickly with distance from the coast. The surrounding countryside for a long distance is a very ancient peneplain underlain by Archaean crystalline and metamorphic rocks, usually capped by thin laterite and sand, and topographic relief is low.

The southern edge of this ancient peneplain is several miles north of the town. In Tertiary times it was the edge of the main land mass with a chain of granitic islands lying offshore. The granites have weathered to provide huge quantities of sand, and an offshore bar appears to have built up and connected the islands together, leaving a channel separating them from the mainland.

This channel gradually filled with marine and paralic sediments, the uppermost of which were saline swamp deposits, until the whole became part of the land mass, with the island chain as the new shoreline. The old channel remains as a low-lying area covered with salt lakes.

However, continued production of sand as a result of weathering of the granites resulted in masses of sand dunes being piled up, mainly by wind action, along the shore. To the west of Esperance these dunes have gradually encroached on the back-dune swamps, so that the salt lake chain loses its character west of Pink Lake. The dunes in places attain a height of nearly 300 feet, although over a large area the interdune flats are at an elevation of 50 feet or less above sea level.

GEOLOGY AND HYDROLOGY

There are thus three quite distinct sets of geological conditions within a few miles of the town. To the north, the granite basement area, with its rainfall decreasing northwards, has intermittent streams which even in winter time have quite saline flows. Many bores have yielded poor supplies and brackish to salty water, although there is an occasional exception. In places thin remnants of Tertiary (Plantagenet Beds) limestone occur, these having been recorded in bores near Shark Lake, six miles north of Esperance, and reported in other localities as far north as Gibson. The limestone is associated with thin sands which in places underlie it, and wherever these Tertiary strata occur the groundwater they contain is of fairly low salinity, that is, less than about 2,500 parts per million. However, in both thickness and extent the aquifers are very limited, and are not a potential source of water for the town.

The strip of salt lake country resulting from the infilling of the back-dune swamp or channel probably has a fairly considerable thickness of Tertiary and younger sediments, but the shallow groundwaters are very saline, and it is not expected that any deeper aquifers which may occur will contain potable water.

The third and remaining area is the coastal sand-dune complex, which is known to contain potable water in the part which lies south of the railway, along the Esperance—Pink Lake road, and southwards towards the rifle range. The Department of Public Works has drilled ten bores, six of which are close together and intended for production, the other four being further afield. There are also some scattered privately owned shallow wells and bores containing very good quality water.

This potable water is a direct result of rainwater runoff from the dunes collecting in the interdune flats and soaking downward into the underlying sands and limestones. The effect is probably more pronounced in those places where a thin and intermittent capping of travertine limestone occurs. Dunes cover an area about 2 miles wide and 5 miles long extending westward from the town itself, and they then spread out to cover a still wider area west and southwest of Pink Lake, where groundwater conditions are unknown. They also continue northeast of the railway, where however, the groundwater quality appears less uniform, and prospects of development consequently not so favourable.

GENERAL

Within the area covered by the dunes, prospects of obtaining the required amount of water are considered reasonably good. However, before consideration is given to enlarging and extending the water supply, the nature and extent of the probable aquifer will have to be proved by drilling. Also, as it has in the past proved difficult to extract the water, consideration will have to be given to proper methods of development. A privately constructed bore at the new drive-in theatre is reported to have a yield of 12,000 gallons per hour, and there is another high-production bore near Pink Lake. Prolonged continuous pumping at such high rates is unwise, as there is a danger of dewatering the aquifer, and possibly increasing the salinity. For a town supply it would be wiser to aim at individual production of 2,000-4,000 gallons per hour, which means using a number of bores simultaneously, and spreading the draw-off over a fairly wide area.

Because of the current rapid expansion of building, the present six town bores are already within or at the edge of the residential area. No sewerage system is available, and the water from these bores can be expected to become increasingly contaminated with detergents from domestic discharge. It may become unusable. Half a mile west of the residential area along the Pink Lake road there is a cemetery, and further west a community rubbish tip, both potential sources of groundwater contamination.

EXPLORATORY DRILLING

Exploratory drilling should be confined to the dune area, which can be subdivided into three parts: one northeast of the railway, the second roughly triangular in shape with apices at Pink Lake, Esperance and the rifle range, and the third extending to the westward of these and south of Pink Lake.

As a part of the general investigation it will be advisable to drill some bores northeast of the railway to establish the areal extent of the aquifer, although this area is not envisaged as a production area.

Considerable quantities of water are expected in the second area which roughly straddles the Esperance/Pink Lake road, but because of possible contamination, there may be some objection to their development.

This still leaves what appears to be a substantial area to the westward in which potable water is expected. Once the extent and thickness of the aquifer and the salinity pattern have been established, consideration can be given to the best locations for production bores, but these unknowns must first be established by exploratory drilling.

Drilling should at first be confined to the interdune flats, which the accompanying plan (Plate 1) shows to be widespread. Moreover, the flats tend to form corridors in a west-southwest direction parallel to the prevailing wind, which will facilitate access.

A programme of drilling 25 bores is suggested, at the sites indicated on the plan, the bores being roughly 40-60 chains apart. Most of these bores will be less than 100 feet in depth, although it would be wise to drill occasional widely spaced bores to 200-250 feet in order to test the quality and occurrence of the deeper water. This should be found out because of the possibility of upward movement of saline water in pumped bores. The strata expected are a sequence of sands and limestones, which should be reasonably good drilling, unless the sands, some of which are fine and not very well consolidated, collapse in the hole. The total drilling footage involved is probably of the order of 3,500 feet.

CONCLUSIONS AND RECOMMENDATIONS

An exploratory drilling programme of 25 bores is recommended at the sites indicated on the attached plan. Careful sampling of waters and strata will be needed.

The programme is designed to establish the extent and thickness of the potable water aquifer and the salinity pattern. The proposed drilling may not do this completely, as at this stage the westward extent of the aquifer can only be guessed at, and no drilling has been suggested near the extensive live sand dune southwest of the rifle range.

Sites have been chosen on the interdune flats, because of ease of access and lesser depth of drilling.

When the suggested drilling nears completion, consideration can be given to whether the problems are sufficiently clarified to enable development work to proceed, or whether more exploratory drilling appears desirable.

EXPLORATORY DRILLING FOR WATER IN THE SANDPLAIN COUNTRY 40 MILES EAST OF HYDEN

by

K. Berliat

INTRODUCTION

Extensive areas of vacant light land east of Hyden (218 road miles east of Perth, via York, Corrigin, and Kondinin) are considered suitable for mixed farming, provided adequate stock water supplies are available. The Department of Agriculture therefore sought advice on the groundwater potential, indicating that some exploratory drilling should precede any attempt to develop farms.

Nine shallow bores were subsequently drilled by contract along the Hyden—Norseman Road, in the vicinity of the Department of Agriculture's research area 40 miles east of Hyden.

TOPOGRAPHY, GEOLOGY

Topographically the area is predominantly undulating sandplain, covered by yellow, loamy sands, carrying a dense vegetation of low scrub. Red clayey soils with good stands of salmon gum, gimlet and morrel, are characteristic of the main depressions trending in a southerly direction. Defined drainage lines with incised channels do not occur. Small scattered outcrops of granite are common, particularly in the more elevated places and it is presumed that granite or basic intrusive rocks underlie the whole area at varying shallow depths.

RAINFALL

One of the main factors controlling the accumulations and quality of shallow groundwater is local rainfall, and records over long periods of time are an important indication of an area's potential.

Rainfall records in the drilling area have not been kept long enough to obtain a picture of the long term pattern. The annual rainfall recorded at the Department of Agriculture's experimental area was 15.66 inches for 1960 and 10.33 inches for 1961. Records from Emu Rocks, 5 miles southwest of the drilling area, show a mean annual rainfall of 11.02 inches over a period of some 50 years. These figures indicate that the area under discussion is situated in a low rainfall, saline groundwater province.

EXPLORATORY DRILLING

The drill sites were chosen to provide groundwater information in various topographical environments including high-level sandplain depressions; long, gentle slopes; areas surrounding granite outcrops; and major topographical depressions.

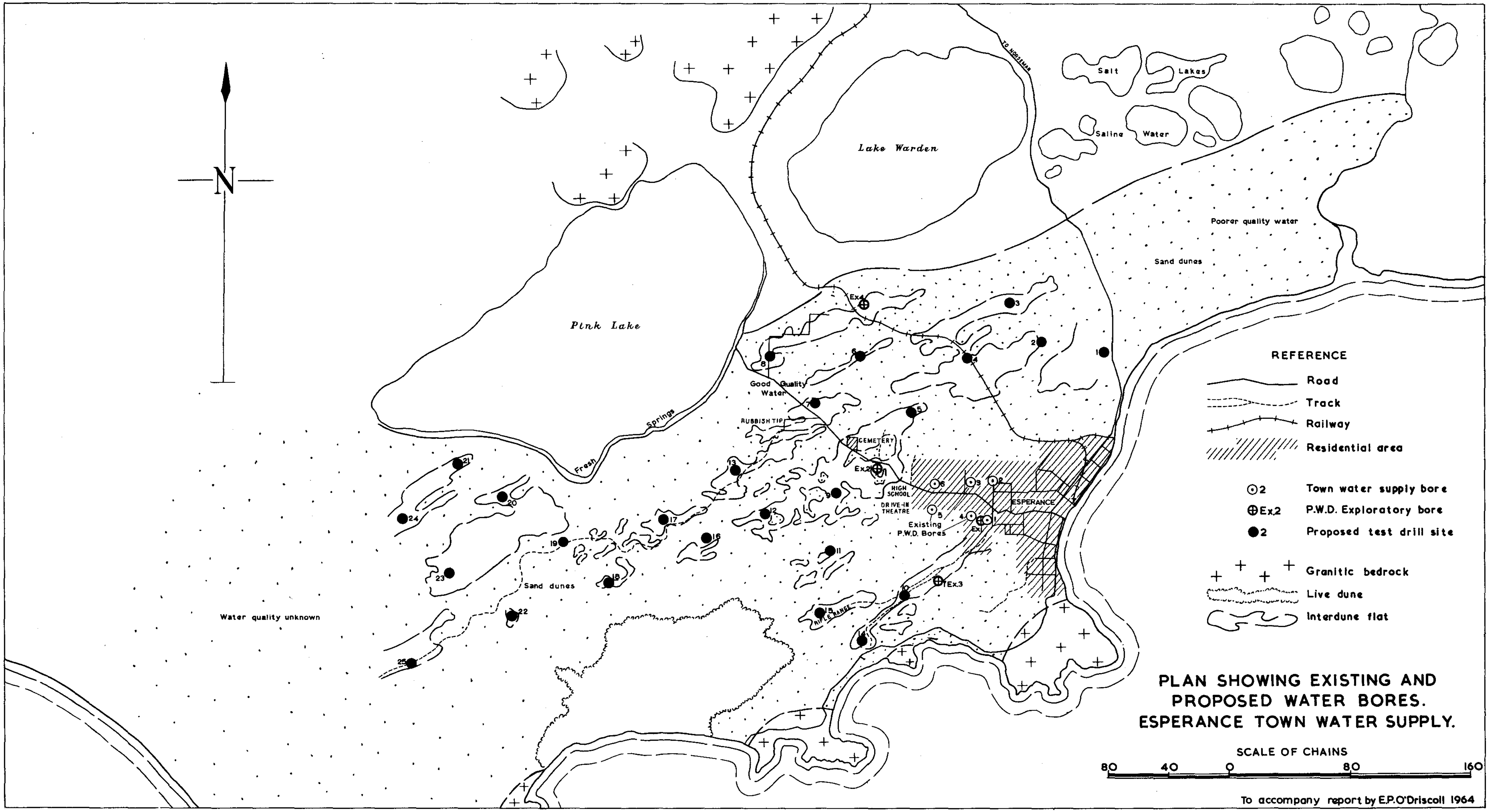
No. 1 Bore, located to test a prominent high-level sandplain depression, was drilled in weathered granite to a depth of 125 feet. Water was encountered at 119 feet, having a salinity of 10,000 p.p.m. (parts per million) total dissolved solids (9,260 p.p.m. NaCl), increasing to 10,600 p.p.m. (9,770 p.p.m. NaCl) at 125 feet. The hole was then abandoned without striking bedrock. The supply was not in excess of 700 gallons per day.

These results gave reasonable grounds to expect that water of lower salinity might occur at points of higher elevation, and No. 2 Bore was therefore sited in the same depression 40 chains west of No. 1 Bore. The bore penetrated 90 feet of decomposed granite and then encountered solid bedrock without striking any water.

No. 3 Bore, near the southern boundary of the Department of Agriculture's experimental area, tested one of the characteristic long, gentle slopes. At 130 feet a small supply of water not exceeding 200 gallons per day was encountered. This water had a salinity of 9,880 p.p.m. total dissolved solids (9,030 p.p.m. NaCl, which increased to 11,900 p.p.m. (11,000 p.p.m. NaCl) at 134 feet, where solid granite was encountered. The supply at the bottom of the hole was 600 gallons per day.

No. 4 and No. 5 Bores were drilled about 20 chains down the slope from the margin of a granite outcrop. There appeared to be good catchment conditions and the objective of the drilling was to test potential accumulations of groundwater draining down the buried granite slope. The bores bottomed in solid granite at depths of 63 and 73 feet and both were dry.

The remaining four bores (No. 6 to No. 9) were drilled to test the salinity of the groundwater in the low lying valley flats crossing the Hyden-Norseman Road about 2 miles east and 4 miles west of the experimental area (see Plate 2). Two of them were dry, reaching solid granite at 70 feet (No. 8) and 39 feet (No. 9). The other two cut water in decomposed granite at 80 feet and 94 feet. The supply in both bores was at least 5,000 gallons per day, but the salinity was very high, 24,900 p.p.m. total dissolved solids (21,100 p.p.m. NaCl) in No. 6 Bore and 36,900 p.p.m. (35,700 p.p.m. NaCl) in No. 7 Bore.

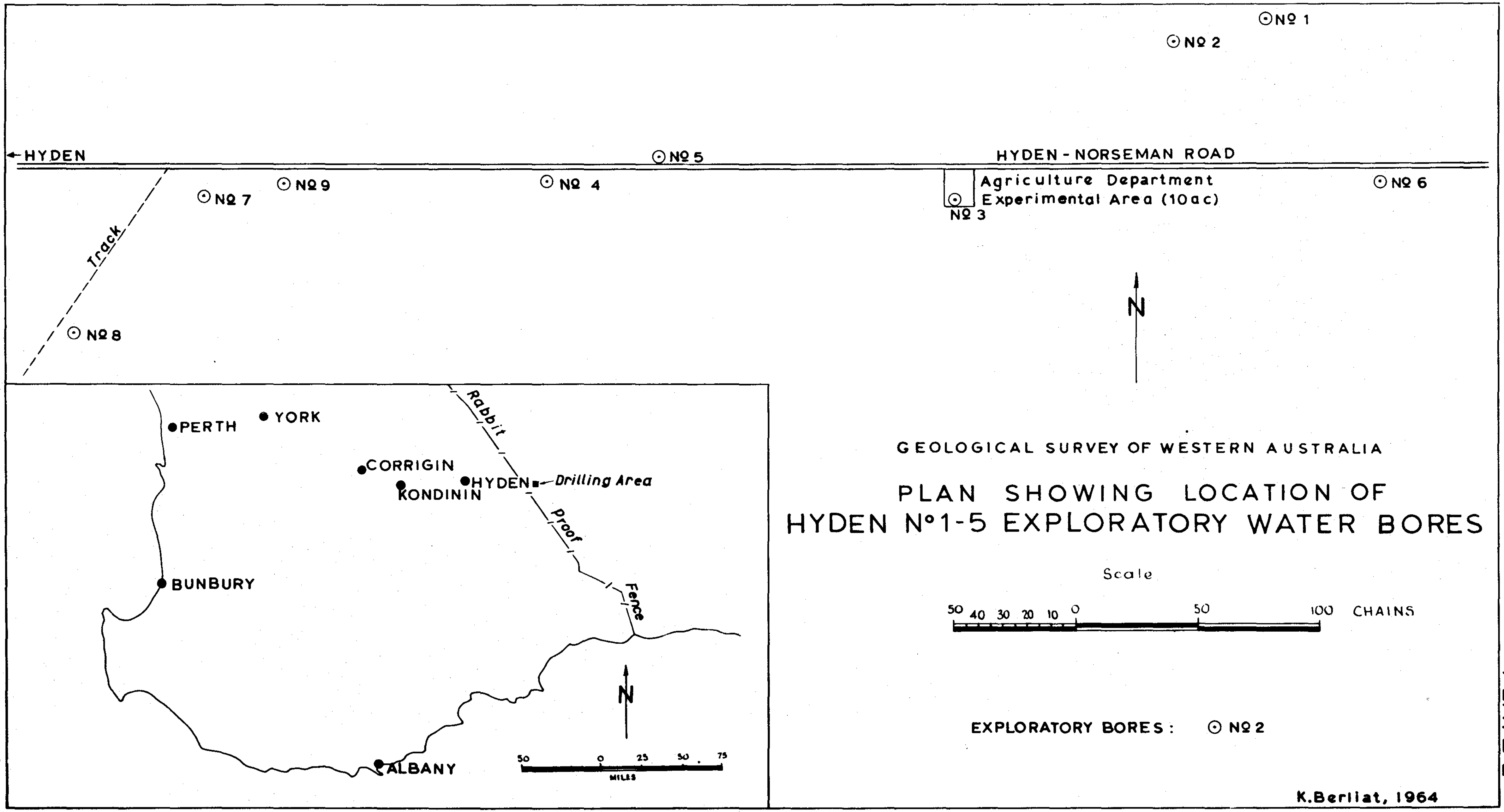


PLAN SHOWING EXISTING AND PROPOSED WATER BORES. ESPERANCE TOWN WATER SUPPLY.

PLATE I

8626

8606



Nº 1
Nº 2
HYDEN
Nº 5
HYDEN - NORSEMAN ROAD
Nº 9
Nº 4
Agriculture Department
Experimental Area (10ac)
Nº 6
Nº 7
Nº 3
Track
N
Nº 8
PERTH
YORK
Rabbit
CORRIGIN
HYDEN
Drilling Area
KONDININ
Proof
BUNBURY
Fence
N
ALBANY
50 0 25 50 75
MILES
GEOLOGICAL SURVEY OF WESTERN AUSTRALIA
PLAN SHOWING LOCATION OF
HYDEN Nº1-5 EXPLORATORY WATER BORES
Scale
50 40 30 20 10 0 50 100 CHAINS
EXPLORATORY BORES: Nº 2
K.Berliat, 1964

PLATE 2

CONCLUSIONS

The exploratory drilling programme of nine bores was confined to a relatively small area in the sandplain country 40 miles east of Hyden. It cannot be considered comprehensive enough to draw final conclusions concerning the groundwater in the region as a whole, but the results suggest that the general conditions are poor.

Groundwater in the major topographical depression is excessively saline, and useless for stock and irrigation purposes.

Bores drilled on the more elevated sites were favourably located from the point of view of catchment and run-off, and the negative results are thought to be due to one or more of the following factors:

1. The configuration of the buried granite surface (bores not located in the lowest portions of the bedrock relief).
2. The low permeability of the decomposed granitic material.
3. The bores were located topographically too low. This applies to No. 1 Bore in particular.

In spite of the fact that in general the results were discouraging, they do not necessarily mean that no stock waters occur. Some of the high-level depressions and gullies may hold some promise of success, provided there are favourable conditions of catchment and run-off, and bores are located in a basement "low". This last condition raises a difficulty, because the depth to hard rock cannot be predicted from surface inspection. However, in the best of cases only limited supplies of water of stock quality can be expected.

The bare granite outcrops on higher ground, a common feature throughout the region, form good catchments only when the run-off is efficiently concentrated. Many granite outcrops are boss-like and shed the water all around their periphery; others are flat, or saucer-shaped, and much of the rain falling on them will simply accumulate and evaporate.

There is a possibility that usable supplies of water might occur in fractured zones in the basement rocks. Drilling in fresh granite with a percussion rig is difficult if not impossible, but if suitable rock drilling equipment is available some bores should be drilled 60 to 70 feet into bedrock. This applies only to areas where conditions are otherwise favourable, but which have failed to yield water from decomposed material. Waters occurring in hard unweathered granite will probably be no better in quality than any shallower water occurring in the same hole, and at the best are expected to be of poor stock quality.

GROUNDWATER IN THE COASTAL SAND DUNES AT LANCELIN, PERTH BASIN

by

K. H. Morgan

ABSTRACT

Inspection of the Lancelin area and test drilling of two bores to depths of 80 and 150 feet in an area about one mile east of the town indicate that probably 1.5 million gallons per acre of domestic quality water is available. Pump rates from a single bore may be more than 16,000 gallons per hour with little drawdown. Ample water is available for town water supply needs.

INTRODUCTION

At the request of the Department of Public Works the Geological Survey investigated the possibility of obtaining a groundwater supply for the town of Lancelin. After a geological inspection, two test bores were drilled in late 1963 (Plate 3). These bores proved the existence of a fairly extensive and comparatively thick zone of usable water a short distance east of the town.

Lancelin is 78 road miles north of Perth and is in an early stage of development. Water supplies are obtained from numerous private shallow bores, wells and rain water tanks. Domestic wastes are disposed of into soakage wells and drains, and wastes from the fish processing plants are mainly pumped into the sea. Beside the permanent population, there is a seasonal influx of holiday makers. The peak population at Christmas is estimated at 2,500.

Present water requirement has been estimated at 17.5 million gallons per year. The average annual rainfall is about 22 inches.

TOPOGRAPHY AND VEGETATION

The town is located near the shore of a sandy bay fringed by scrub-covered foredunes rising about 10 feet above sea level. Behind these dunes are beach ridges, rising 3 to 8 feet above the general level and covered by coastal heath.

At high tide the water table rises and saturates the interdune area, on which most of the buildings and roadways are located.

Farther inland is an eroded, bare, flat strip of rocky country, 20 to 40 chains in width and standing about 12 feet above sea level. Still farther eastward is a half mile wide belt of mobile sand dunes rising to slightly more than 50 feet above sea level.

Table 1

STRATIGRAPHIC UNITS AT LANCELIN

Bay Area	Shore Area	Eroded Rocky Area	Sand Dune Area
Contemporary marine sand	Contemporary foredunes		Sand dunes
Marine sand	Beach ridges { aeolian sand beach sand Stratified marine sand Buried limestone reefs	Aeolianite Travertine cap	Aeolianite Travertine cap
	Erosion Surface		
Coastal Limestone	Coastal Limestone { aeolian marine	Aeolianite Part leached beach sand	Aeolianite with solution pipes highly leached beach sand
	Disconformity		
	Upper Cretaceous marl (Lancelin Beds)		
	Unconformity		
	? Jurassic		

GEOLOGY AND HYDROLOGY

The rock sequence is set out in Table 1.

The youngest rocks are the contempoary foredunes along the coast, the mobile sand dunes a half mile east of the shore, and the marine sand being deposited in the bay at the present time. These are composed mainly of marine carbonate sediments.

Stratigraphically below the sand dunes is a sequence of friable calcareous sand and calcarenite. In the eroded rocky area and the sand dune area calcareous aeolianite, with an abundance of rootlet structures and cocoon casts, overlies a travertine band that represents an older land surface. Near the shore the sequence of calcareous sand and calcarenite is mainly of marine origin, and comprises low sandy beach ridges of aeolian sand overlying a coarse grained shelly beach sand. Shallow bores and wells in the aeolian ridges yield small water supplies, but screens or spears in the bores soon become blocked with fine sand and carbonate cement. For this reason wells are more effective. The beach deposit yields slightly larger supplies of more saline water. Being close to the surface both these aquifers are subject to pollution.

Below the beach sand and extending to 30 feet below sea level on the shore line is stratified fine to coarse-grained fossiliferous marine sand with sea weed beds. It contains brackish to saline water, brown in colour and usually has a strong sulphurous odour. An abnormally high nitrate content in three water samples suggests pollution (see Table 2).

Table 2

WATER ANALYSES OF SAMPLES FROM SOME BORES AT LANCELIN

(See sketch map for locations)

Bore Sample No.	9809	9812	9816	9811	9813	9814	9815	Bore 2B Final Sample
Specific Conductivity 20°C	2140	....	....	....	....	....	....	680
Odour	Nil	Nil	Nil	Hydrogen sulphide	Hydrogen sulphide	Nil	Nil	Nil
pH	7·4	7·2	7·4	6·7	6·7	7·6	7·0	7·6
Analyses in parts per million :								
Calcium, Ca	78	....	....	....	....	....	....	71
Magnesium, Mg	59	....	....	....	....	....	....	15
Sodium, Na	351	....	....	....	....	....	....	69
Potassium, K	16	....	....	....	....	....	....	3
Bicarbonate, HCO_3	299	....	....	....	....	....	....	235
Carbonate, CO_3	Nil	....	....	....	....	....	....	Nil
Sulphate, SO_4	89	....	....	....	....	....	....	14
Chloride, Cl	610	544	112	874	336	144	579	132
Sodium Chloride, NaCl	....	897	184	1440	554	237	954	....
Nitrate, NO_3	28	4	2	....	....	....	....	....
Silica, SiO_2	10	....	....	....	....	....	....	....
Iron, Fe	less 0·1	....	....	....	....	....	....	not detected
Total : by conductivity	1500	1360	410	2000	860	480	1450	480
by summation	1540	....	....	....	....	....	....	439
Hardness (calculated as $CaCO_3$) :								
Total hardness	438	....	....	....	....	....	....	239
Bicarbonate hardness	245	....	....	....	....	....	....	193
Calcium hardness	195	....	....	....	....	....	....	177
Magnesium hardness	243	....	....	....	....	....	....	62
Non-carbonate hardness	193	....	....	....	....	....	....	46

Most of the present water supplies are extracted from the beach sand and the stratified marine sand described above.

Limestone reefs at the base of the marine sand represent the marine top of the Coastal Limestone. This erosion surface is 20 to 30 feet below sea level under the shore and is the marine equivalent of the travertine cap in the eroded rock and sand dune areas to the east. Where exposed the Coastal Limestone has a hard travertine cap with "karst" features and solution pipes extending below sea level. Under the travertine cap it is friable and easily wind eroded. Below water level it is also friable. The upper part is aeolian, the basal part shallow-water marine, with coarse-grained beach deposit between. In Bores 1 and 2B the very coarse-grained sections, between 20-35 feet and 45-70 feet respectively, are thought to be the beach deposit leached of carbonate cement and shell fragments. Under the town area the beach deposit is partly leached of carbonates and the comparatively good water sometimes found there is thought to result from intake in the sand dunes to the east.

At the shore the Coastal Limestone extends to approximately 100 feet below sea level and unconformably overlies impervious Upper Cretaceous (Campanian) marls having a thickness of at least 45 feet. The unit is younger than any previously dated Cretaceous rocks in the Perth Basin and has been assigned the provisional name, Lancelin Beds (Edgell, 1964). They probably overlie Jurassic sediments which are expected to be water bearing.

DRILLING

The drilling and pump testing were done by contract, with the following results:

Bore No. 1 reached a depth of 80 feet, passing through domestic quality water from 15 feet to about 70 feet. Below this, the salinity quickly increased. This particular locality should not be developed, as heavy pumping will result in encroachment of saline water.

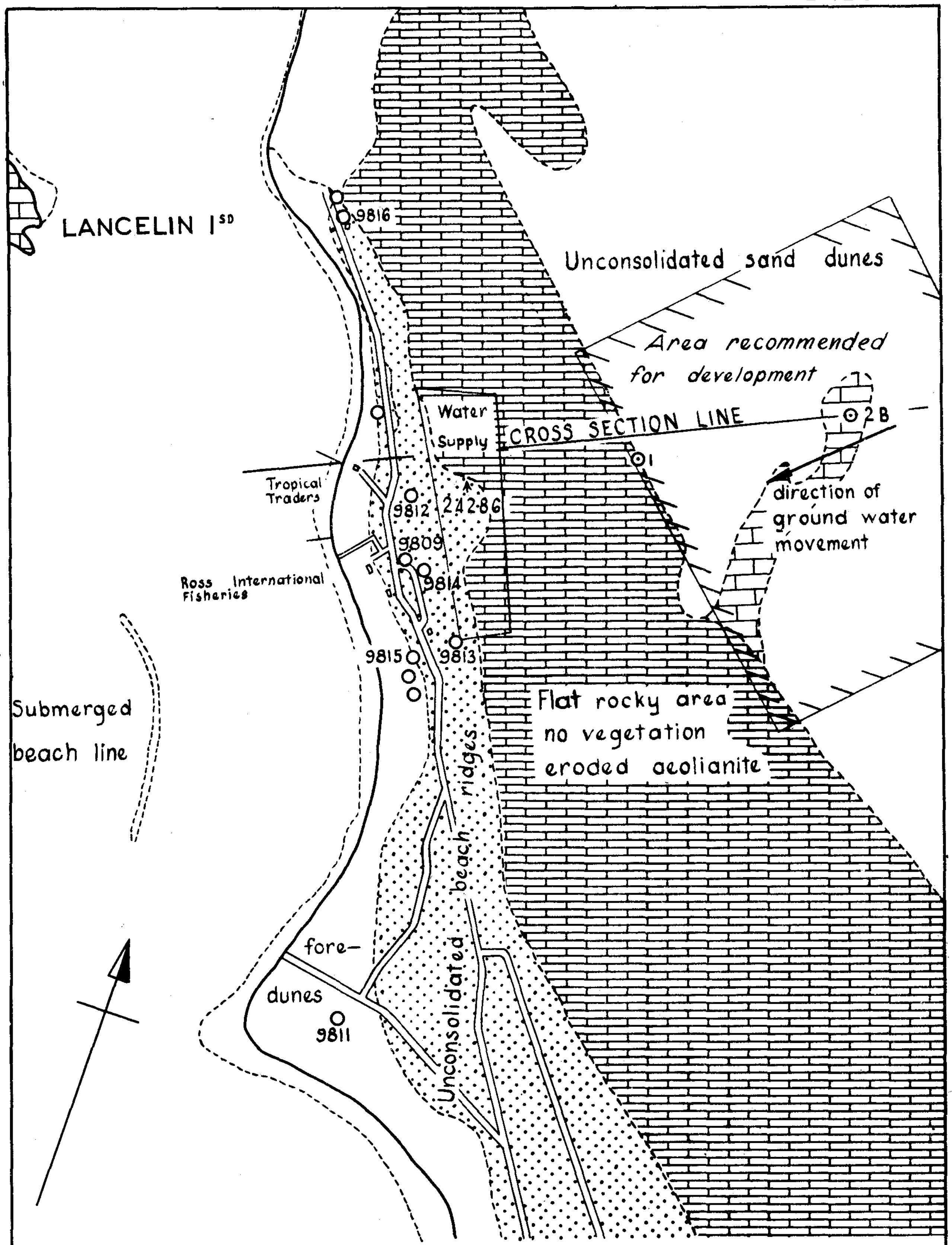
Bore No. 2B was drilled to a depth of 150 feet and intersected domestic quality water between 8 feet and 90 feet, below which the salinity also increased rapidly. This bore was screened between 50 and 60 feet, and test pumped at 12,500 gallons per hour for 20 hours, with a drawdown of 1.1 feet; then at 16,200 gallons per hour for 10 hours, with little alteration in the drawdown. During this 30 hours the salinity rose from 410 p.p.m. (parts per million) total dissolved solids to 525 p.p.m. total dissolved solids (see Table 2).

CONCLUSIONS AND RECOMMENDATIONS

Drilling and testing have proved the existence of a large volume of water suitable for the town supply.

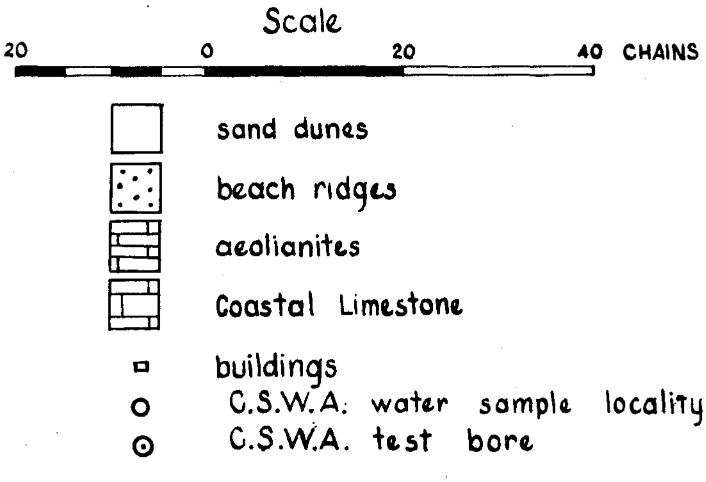
In the drilling area, the salinity to a depth of 70 feet is expected to average 400 p.p.m. total dissolved solids. Water of salinity greater than 1,000 p.p.m. total dissolved solids occurs below 70 feet in Bore No. 1 and below 90 feet in Bore No. 2B (Plate 4). Similar conditions are expected throughout the sand dune area, half a mile from the shore. The thickness of beds containing water of salinity less than 1,000 p.p.m. decreases rapidly towards the coast, whereas the zone of diffusion of brackish to saline water increases in thickness towards the coast.

Assuming an average thickness of 30 feet of beds containing usable water and a specific yield of 20 per cent, there is probably available 1.5 million gallons per acre from water already in storage. An area of about 15 acres, if completely pumped out, would supply town needs for one year, and a square mile would last some 40 years, even if there was no recharge from rain.



GEOLOGICAL SURVEY OF WESTERN AUSTRALIA

GEOLOGICAL SKETCH MAP OF LANCELIN AREA



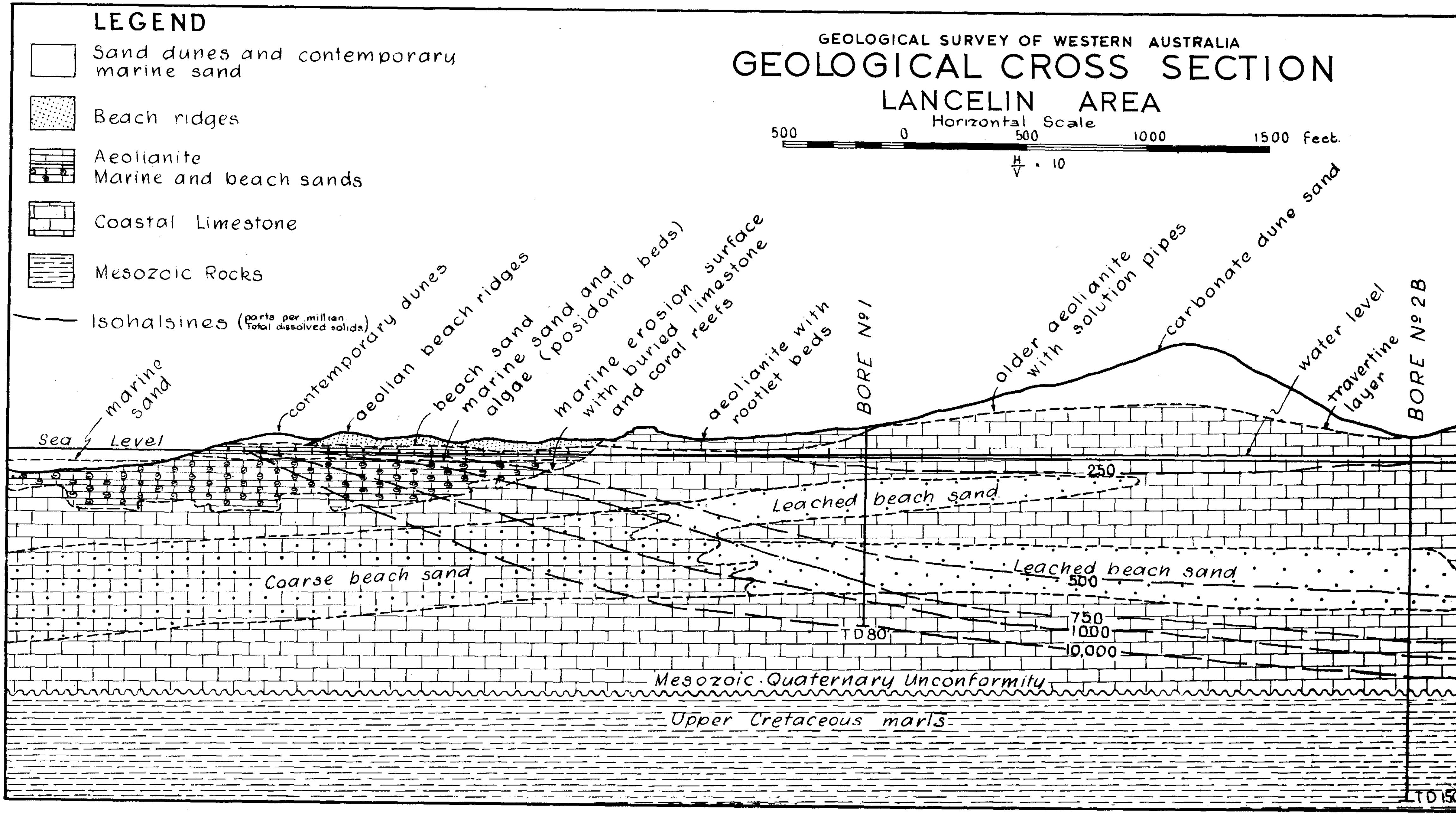

LEGEND
Sand dunes and contemporary marine sand
Beach ridges
Aeolianite
Marine and beach sands
Coastal Limestone
Mesozoic Rocks
Isohalsines (parts per million Total dissolved solids)
GEOLOGICAL SURVEY OF WESTERN AUSTRALIA
GEOLOGICAL CROSS SECTION
LANCELIN AREA
Horizontal Scale
500 0 500 1000 1500 Feet.
H/V = 10
marine sand
Sea Level
contemporary dunes
aeolian beach ridges
beach sand
marine sand and algae (posidonia beds)
marine erosion surface with buried limestone and coral reefs
aeolianite with rootlet beds
BORE No 1
older aeolianite with solution pipes
carbonate dune sand
water level
travertine layer
BORE No 2B
250
Leached beach sand
Leached beach sand
Coarse beach sand
500
750
1000
10,000
TD 80'
Mesozoic-Quaternary Unconformity
Upper Cretaceous marls
TD 150'

PLATE 4

8612

An annual accretion of 3 inches of rain to the groundwater would provide about 68,000 gallons of recharge per acre per year. To balance the current requirement of 17.5 million gallons per year, an area of about 300 acres is needed.

That recharge does occur is apparent from the hydraulic gradient, which rises from mean sea level to about 2.1 feet higher at Bore No. 2B, a gradient of about 1 : 2,300. This gradient continues eastward and considerable recharge resulting from westward-moving groundwater would accur if the sand dune area was pumped.

The area of good quality groundwater probably exceeds the required 300 acres by a substantial margin, so that unless pumping rates in the future are much higher than expected, there appears to be an ample supply of groundwater available from the sand dune area east of the town.

Privately constructed bores in the town show that the shallow aquifer used at present has insufficient reserves for development, and production bores will have to be drilled a mile or so eastward and within the area recommended for development on the sketch map.

To spread the drawoff, and reduce the likelihood of saline waters rising from below and causing deterioration of water quality, it is suggested that more than one pumping bore be used.

REFERENCE

Edgell, H. S., 1964, The occurrence of Upper Cretaceous marine strata of Campanian age at Lancelin, Perth Basin: West. Australia Geol. Survey Ann. Rept. 1963.

APPENDIX 1

BORE COMPLETION REPORT LANCELIN No. 1

Location: Crown Reserve 22287, 40 chains east of Tropical Traders' Jetty, at the base of high drift sand dunes.

Drilled: October, 1963.

R.L. of Ground Surface: Approximately 20 feet.

Water Rest Level on Completion of Bore: 15 feet.

Total Depth: 80 feet.

SUMMARY OF LOG

		Strata	Water Samples	
			Depth (feet)	p.p.m./ t.d.s.
Coastal Limestone	Aeolianite	*Calcarenite* (0–20 feet) : white to light yellow, fine to coarse grained stratified, friable calcarenite and marly calcarenite. Shell fragments common between 10–15 feet.	15 20	250 300
	Leached beach sand	*Interbedded coarse grained calcarenite and clean sand* (20–35 feet) : light yellow, clean, medium to coarse grained, friable calcarenite interbedded with clean coarse grained quartz sand with carbonate grains.	25 30 35	305 310 320
		Poorly sorted calcarenite (35–55 feet) : deep yellow to light yellow, medium grained, friable marly calcarenite. Moderate sorting between 50–55 feet.	40 45 50 55 60	335 450 510 540 570
		Limestone (55–80 feet) : deep yellow to light yellow, hard calcarenite with a travertine layer between 55–60 feet.	65 70 75 80	610 680 2,950 4,300

APPENDIX 2

BORE COMPLETION REPORT LANCELIN No. 2

Location: In a valley in sand dues 70 chains east of Tropical Traders' Jetty.

Drilled: October-November, 1963.

R.L. Ground Surface: 10.2 feet.

Water First Encountered: Approximately 9 feet.

Water Level in Completed Bore: 8 feet.

Total Depth: 150 feet.

SUMMARY OF LOG

		Strata	Water Samples	
			Depth (feet)	p.p.m./ t.d.s.
Coastal Limestone	Travertine cap	*Boulder calcarenite*, 90% (0–25 feet) : light yellow to cream, friable, medium to coarse grained calcarenite with abundant small shells and shell fragments, and boulders of deep yellow to grey travertine. Marly between 10–20 feet.	15 20 25	270 280 400
	Aeolianite	*Calcarenite* 90% (25–45 feet) : light yellow to deep yellow, part cemented, friable, fine to medium grained calcarenite. Fine grained calcarenite. Fine grained and marly between 35–45 feet.	30 35 40 45	445 495 495 500
	Leached beach sand	*Quartz sand* 95% (45–70 feet) : light yellow to yellow, mobile, well sorted, coarse and very coarse grained quartz sand with 5–10% carbonate-quartz sand accretions. Quartz grains are colourless to stained yellow with a rounded to highly rounded smooth to matt surface and an 0·4 to 0·6 sphericity.	50 55 60 65 70	275 300 440 500 620
		Limestone 90% (70–105 feet) : light yellow to yellow, soft to hard, medium grained, quartz sandy limestone.	75 80 85 90 95 100	650 660 660 660 8,220 15,000
Upper Cretaceous	Lancelin Beds	*Marl* (105–150 feet+) : green-grey marl, slightly micaceous to slightly sandy, with abundance of macrofossils including *Inoceramus* sp. and brachiopods.	105 110 115	19,000 19,000 16,000

GEOLOGICAL INVESTIGATIONS AT WUNGONG BROOK UPPER DAM SITE

by

F. R. Gordon and J. D. Wyatt

ABSTRACT

An earthfill dam 170 feet high, across Wungong Brook, and situated 70 miles south of Perth, is proposed on an alternative site to one previously investigated 2 miles downstream. Detailed investigation of the area included shallow auger holes; two diamond drill holes; plane table geological mapping; geophysical seismic traverses: with electric logging and water pressure tests of the completed drill holes.

The proposed dam will be located on a weathered granite gneiss complex of residual soils with minor alluvial material close to the stream channel. Outcrops of relatively fresh, open jointed granite gneiss are scattered throughout the foundation area along the river bed and valley slopes.

Four major dolerite dykes intrude the granite gneiss, one of which reaches a maximum width of 300 feet. Minor occurrences of a basic dyke or amphibolite lens were intersected during the drilling of the two diamond drill holes, which were sited close to the river near the proposed centreline of the dam. Thirty-three auger holes were drilled on both sides of the stream channel. The depth of the zone of decomposition ranged from 3 to 25 feet.

The weathering profile of granitic rocks in the Darling Range was investigated in detail because of the variable nature of materials available for use in the construction of the earthfill dam.

In order to restrict the passage of water through the abutments and foundation area of the dam, it is recommended that a cut-off wall be constructed down to impervious clays together with a grout curtain in the jointed granite gneiss.

INTRODUCTION

As an alternative to a gravity dam structure at the lower site on Wungong Brook, which has been under study for many years, design engineers of the Metropolitan Water Supply Board have proposed an earthfill dam 170 feet high, at a site 2 miles upstream.

This proposed "upper" dam site is approximately 30 miles by road from Perth. Access is by way of the South-Western Highway to Byford and thence east for 6 miles, along formed gravel roads and forest tracks.

The area is shown in Lands Lithograph No. 341 B/40 and is covered by Canning Location Nos. 618, 387, 124, 345, 462 and 373.

The section on "Geology" was contributed by J. D. Wyatt, who mapped the area at a scale of 100 feet to an inch using plane table and telescopic alidade traverses.

TOPOGRAPHY

The topography is rugged, and short intermittently-flowing streams have incised valleys to a depth of some 250 feet into the weathered Precambrian igneous complex of the Darling Peneplain. No active downcutting is taking place at the present time.

The Wungong stream course is rarely straight, and the dominant directions appear to be controlled both by major jointing patterns, which may be sheared, and the differential erosion of the various rock types.

The valley is asymmetric in cross-section: abundant steep-sided rock usually outcrops on the northern valley slope, and deeply-weathered gently-sloping residual soils on the opposite slope. The narrower sections suitable for damming are rarely continuous for more than a few hundred feet, but open out into small, alluvium-covered flats which are subject to winter flooding. These flats may conceal appreciable thicknesses of permeable gravels and sands.

GEOLOGY

ROCK TYPES

The local rocks consist dominantly of granite gneiss which is intruded by dykes of dolerite, pegmatite, and quartz, and veinlets of epidote. A weathered and lateritised mantle of varying thickness, consisting of lateritic soils on the valley slopes and massive laterite on the hill tops, approximately 650 feet above sea level, effectively obscures the crystalline parent rock.

Granite Gneiss

The granite gneiss is a medium to fine-grained acid rock, which is weakly gneissic in surface exposures. In size and extent, the outcrops range from extensive tabular exposures to isolated boulders which may or may not be in situ. In some instances where abundant outcrop exists on the steeper hill slopes, strong vertical jointing parallel to the river has allowed rock slide to occur in the larger boulders.

Abundant outcrop occurs within the foundation area of the proposed dam, especially in the vicinity of both upstream and downstream toes.

Dolerite Dykes

At last three and possibly four major dykes intrude the granite gneiss, but none of these appears to intersect the foundation area of the proposed dam. Where contact with the granite gneiss is visible, marginal chilling is evident in these otherwise coarse-grained dykes.

The smallest dyke mapped was 65 feet wide and could be traced for almost half a mile, while the largest was apparently 300 feet wide, although its marginal contacts were obscured by soil cover. All the dykes are frequently jointed, and on weathering are reduced to small blocky fragments ranging in size from 6 to 12 inches square. By contrast the granite gneiss outcrops tend to weather to conchoidal boulders showing only incipient jointing.

The dolerites strike in directions related to one or another of the major joint sets of the area, which suggests that emplacement was influenced by jointing.

Geophysical traverses using a seismic timer along three lines parallel to the proposed centreline of the dam, reveal the presence of a subsurface ridge, which has been interpreted as a dolerite dyke (Rowston, 1963). Examination of the area which has both a thick soil and vegetation cover has shown the existence of several small dolerite-type fragments. These fragments appear to be in a zone that strikes at 045°, but this alignment could be due entirely to debris slide and soil creep down slope, as there is no evidence of a dolerite dyke intersecting a bare granite gneiss outcrop only 150 feet away and along the strike. However, occasional basic pebbles having the appearance of dolerite are found further along the hill slope at the same elevation. This supports the idea that a dolerite dyke exists, although not exposed at the surface.

A comparison of the "dolerite" fragments from the left abutment with other pieces of basic rock found on the right bank of the Wungong Brook near Area 1 (Plate 5), suggests that the suspected dyke may prove to be a basic lens within the granite, with little lateral extension. This would explain the lack of evidence of a dolerite cutting the bare granite outcrop of Area 9 (Plate 5). Unfortunately the almost continuous blanket of soil cover makes confirmation by surface mapping difficult.

Pegmatite Dykes and Quartz Veinlets

In addition to the basic dolerite, minor acid intrusives in the form of pegmatite dykes and small quartz veinlets are evident.

The pegmatitic phase of the granite, which appears in several of the exposures, is most noticeable in an outcrop at the apex of the downstream toe of the proposed dam, where one dyke 5 feet wide was recorded.

The quartz veinlets are usually very small in size, being only 1 to 2 inches in width with random orientation. In two localities, closely-spaced parallel veinlets, sometimes showing slickensiding, suggest a possible shear zone.

Laterite

The massive laterite outcrop which forms a capping over all the rocks, irrespective of type, is generally found only above the 650 foot level, although floaters and scree fragments are found on the lower slopes. This capping shows a thickness of 3 to 5 feet, reaching the maximum higher up on the valley slopes above the top water level of the proposed dam.

JOINTING

A total of 133 joints was measured during the mapping of 11 major outcrop areas (see Plate 5) and from these it was possible to prepare a composite joint rosette containing seven major joint sets, which includes 74 per cent of the readings taken.

The two most abundant joint partings, due north and N 80° E, are parallel to local river direction changes, which would suggest a joint control for part of the river course.

Minor quartz-filled shears were also noted parallel to the predominant joint parting, which is aligned due north, and as this is also a common river channel direction, control by shearing is also possible.

The joint sets have influenced the emplacement of the dolerite dykes and minor quartz epidote veinlets, as veinlets can be directly related to one or another of the main joint sets.

An examination of the rosettes prepared for each major outcrop shows that all except one are similar, the exception being Area 5 (see Plate 5) which is singularly lacking in north-trending joints and also shows a preponderance of flat-lying planes. This exposure occurs as an isolated, large boulder in a small alluvial flat, suggesting that it may not be in situ, but is instead a talus block from an outcrop further upslope.

Several prominent, relatively flat-dipping exfoliation surfaces were noted dipping towards the river on both valley slopes, the majority of which occur on the right bank. One of these showed a small water seepage. As exfoliation joints are considered the result of expansion following the removal of overlying material, they tend to be roughly parallel to the topographic surface. The significance of these extensive surfaces is that they may act as passages for water under pressure.

SUMMARY

1. Shearing is probably at a minimum with only minor slickensiding and quartz vein intrusion.

2. The major rock types exposed in outcrop are homogeneous granite gneiss and dolerite which, although strongly jointed, show little surface evidence of crush zones or major shearing.

3. The large dolerite dykes appear to be confined to the area upstream of the dam.

4. A considerable portion of the river channel in the foundation area shows fresh granite outcrop.

5. There is no evidence of any thick alluvial deposits in the section chosen for the proposed dam, although deeper alluvial zones may occur both up and downstream.

EXPLORATION

AUGER DRILLING, 1962

In 1962 a soils investigation programme was undertaken by personnel of the Metropolitan Water Supply Board. Eleven auger holes were drilled, five of which were situated on Vardi Road, a forest track on the northeast or right bank of Wungong Brook, at an elevation of about 560 feet, and the remainder were on the southwest bank on a track at about 670 feet (Plate 6). The holes on both sides of the brook were about 100 feet apart, and were symmetrically disposed about the proposed centre line. The holes were drilled by a Gemco auger drill to "solid rock" or to a depth of 50 feet, whichever was less. The drill logs and some drive samples were made available to the Geological Survey, and these have proved valuable in a preliminary assessment of the state of rock weathering.

Hole No.	Depth to Rock	Nature of Overburden
	feet	
A1	22	Laterised weathered granite gneiss, very firm.
A2	18	Weathered granite gneiss.
A3	24 (?)	Decomposed dolerite clay and boulders.
A4	5	Alluvium, scree.
A5	18	Weathered granite gneiss, very firm.

The holes on the right bank were all about 20 feet above the level of the stream bottom, and in all holes except Hole A3, rock was encountered at comparatively shallow depths, with the overburden consisting of minor alluvials and residual granitic soils. Hole A3 was drilled into a weathered dolerite dyke and is of considerable engineering interest as there are practically no surface indications of the existence of such a zone of deep weathering or the presence of a different soil type. From the log and samples, five soil horizons can be distinguished:

A Horizon: Top soil with humus.

B Horizon: Residual grey clay, compact and dense.

C Horizon: Residual grey clay with rock structure, and small boulders of dolerite. There is a high voids ratio and permeability, and a high shear strength and resistance to compression where undisturbed.

D Horizon: Firm decomposed rock.

E Horizon: Fresh dolerite.

It is not certain that the hole bottomed on solid dolerite or on a boulder in the C Horizon. The soil samples from the B and C Horizons had very poor engineering properties, and knowledge of the extent and direction of this dyke would be desirable. It would be necessary to excavate at least as deep as firm dolerite where this dyke is exposed in the foundation area. Otherwise the auger drilling results are much as expected, with granite gneiss reasonably close to the surface.

The holes on the track on the western valley slope showed depths of over 40 feet before solid rock was encountered:

Hole No.	Depth to Rock	Nature of Overburden
	feet	
A6 and A7	Over 50	Clay sequence.
A8	Over 50	Sandy clays, " easy drilling in clays."
A9	44	" Easy drilling to 20 feet, then hardens."
A10	39	" Easy drilling in reddish clays."
A11	Over 50	" Easy drilling in clays."

From the samples taken from Holes A6 and A7 and knowledge gained from other sampling programmes, an in situ detailed weathering profile has been established and this is given in Table 1. The thickness of the weathered mantle is dependent largely on the mineral character and grain size of the bedrock, deeper weathering being found in areas where micaceous bands are prominent, and bedrock highs where quartzose gneiss is present.

GEOPHYSICAL TRAVERSES

Five seismic lines were traversed with a Dynametric R117 seismic timer (Rowston, 1963). Three parallel lines, 100 feet apart were centred on the proposed centre line and extended from Vardi Road, just above Wungong Brook on the northeast bank, to the forest track on the southwest bank. These lines were tied with a traverse parallel to the river on the southwest bank, and another traverse along Vardi Road. The differentiation made on the basis of velocity groups allows room for different interpretations as to the nature and origin of "sandy clays" in particular, and this point has been investigated by further auger holes.

The most interesting feature of the seismic results was the indication of the presence of a topographic ridge in the bedrock profile. This feature appears to strike about 120° which is parallel to the stream and it is no more than 35 feet wide. The suggestion has been made that it is a resistant dolerite dyke. This may be likely because two dolerite dykes south of the foundation area have a similar strike, which is also a major joint direction. Examination has revealed dolerite rubble in two places close to the inferred position of the dyke, but there are no other surface indications. An explanation of almost equal merit would be that the ridge is a more quartzose band in the gneissic sequence.

DIAMOND DRILLING

The geological problems associated with this site were mainly concerned with the presence in the river bed of dolerite dykes and associated fault zones, which transect the foundation at right angles in the left bank. Two diamond drill holes were proposed to resolve these questions as far as possible, and further auger drilling was programmed to supplement this work (Plate 6).

Diamond Drill Hole No. 1 was sited upstream of the proposed centre line on the left bank, at a depressed angle of 40° and a bearing of 004°M. It was laid out to cross under the stream bed at right angles. This would explore the possibility of river channel control by faulting or major jointing, and investigate the suspected presence of a dolerite dyke striking across the river from Gemco Hole A3. The second diamond drill hole was located close to No. 1, but was drilled in the opposite direction into the left abutment, in order to investigate the bedrock ridge suggested by the seismic timer traverses. The drilling was done by the Mines Department Drilling Section using a Mindrill A2000 machine.

Diamond Drill Hole No. 1 was drilled to 150 feet 6 inches in 9 days; it encountered 32 feet of silty clay overburden above 21 feet of highly jointed dolerite. Broken granite gneiss close to the dolerite contact was succeeded by a quartzose granite gneiss with a well developed joint system. There were three zones of core loss. One foot 3 inches was lost at 51 feet 3 inches hole depth at the dolerite-gneiss contact which was probably faulted; 9 inches of loss occurred between 60 and

61 feet, probably due to major joint intersections in a broken zone; and 6 inches of core was not recovered at 131 feet hole depth in a very coarse-grained quartz vein.

Diamond Drill Hole No. 2 was drilled at a depressed angle of 30°, and the target depth of 80 feet was reached in 4 days with 2 shifts operating. About 16 feet of weathered granitic soil was encountered, and the solid rock proved to be mainly pegmatite and quartzose granite gneiss. Following a zone of breakage at 62 feet, a core loss of 1½ feet coincided with a zone of complete loss of drilling water, and this probably indicates the presence of a shear zone. A band of dark green amphibolite schist about 4 feet across was intersected below the shear zone, followed by the granite sequence with pegmatite bands.

The shear zone and amphibolite schist were intersected near the position which had been anticipated for the ridge-forming rock from the geophysical traverses, but this material would undoubtedly be more easily weathered than the enclosing granite gneiss so the hole failed to resolve this problem.

ELECTRIC LOGGING

D.D.H.s 1 and 2 were electrically logged by D. L. Rowston with the Geological Survey's Widco well logger. Single point resistivity and self potential logs were recorded. In each case the correlation with the geological log was good, and furthermore, some features of the log were obviously diagnostic of open major joints as revealed by water pressure testing. As this was the first occasion in Western Australia that electrical logging had been used on engineering drilling exploration, the clarity of the results was encouraging. The major application of logging would be in areas of high core loss, and for this reason the indications of shearing shown in the relevant section of D.D.H. 2 was helpful in the final assessment of subsurface conditions.

The following correlations are tentative only and may be modified by further experience:

(1) Sharp, high point resistivity peak with sharp positive self potential peak is equated with zones of high water loss in open joints.

(2) Sharp negative self potential peak and sharp minimum point resistivity peak occurs in shear zones with schist filling.

(3) Minor negative facing peak in self potential and minor low facing point resistivity is correlated with pegmatite and quartz veins in granite gneiss.

(4) Granite gneiss has a positive self potential and high point resistivity as compared with dolerite.

WATER PRESSURE TESTING

The two diamond drill holes were tested for water leakage by engineers of the Metropolitan Water Supply Board. There were four zones of leakage in D.D.H. 1. The first was between 77 and 81½ feet hole depth, corresponding to a zone of breakage noted in the core, where five joints dipping between 65 degrees and 75 degrees show slaty faces and some slickensides. The main joint is open 1/10 inch, and is uneven and partly filled. The second was between 87 and 90 feet, where the water loss probably correlates with a group of three clay-faced joints that dip between 30 degrees and 45 degrees. The third was the main zone of water leakage between 106 and 109½ feet, where a system of four open joints between 106 feet and 107 feet is probably the reason. Openings of 1/5th to 1/10th inch show in the parallel joints that dip at 70 degrees to the core. Resolution of this plane with reference to foliation indicates joints striking due north and dipping at 45 degrees. The fourth, a further zone of water loss at 120½ to 123½ feet, is attributed to a zone of breakage associated with a 1 foot wide coarse-grained quartz vein.

The most surprising aspect of the water pressure tests in D.D.H. 1 was the fact that no significant water losses were recorded from the zone of heavy breakage between 32 and 62 feet. Most of the intensely jointed dolerite dyke between 32 and 50 feet was cased during drilling; the zone of core loss at the contact between dolerite and gneiss, and a sheared section that corresponded to a zone of drilling water loss, showed every indication of allowing water movement.

In D.D.H. 2 the fact that no significant water losses were recorded is surprising, as core loss, non-return of drilling water, and a shear zone on the electric logs, were recorded for the zone between 60 and 65 feet.

AUGER DRILLING 1964

The picture of the site gained from the initial investigations was general rather than complete, but the main problems were apparent. The right abutment had not been explored at all apart from the rather negative evidence gained from adjacent granite gneiss outcrops. On the lower slopes of this abutment and in the river bed, the presence of a dolerite dyke or dykes had been proved by auger hole A3 and D.D.H. 1, but the directions, width and full depth of weathering was not known with certainty. On the left side of the valley, the composition of the ridge which was shown on seismic traverses was not determined by diamond drilling, and it was possible this feature resulted from the presence of a dolerite dyke. The engineering significance of dolerite dykes is the fact that one or both of the margins is often faulted, and therefore broken and weathered, constituting a leakage path if cutting the earth dam.

A further Gemco auger drilling programme of 21 holes was devised in order to fill in the gaps in the knowledge of foundation conditions, and the results may be summarised:

(1) The bedrock ridge defined by seismic survey was proved to be a quartzose band in the granite gneiss (Holes B16, B17, and B18).

(2) The dolerite dyke originally intersected by Hole A3 on the right bank was approximately 40 feet wide. On the left bank definite intersections were made with dolerite in D.D.H. 1 and Hole B11.

(3) Palynological examination by H. S. Edgell (pers. comm.) of spores from samples from Holes B9 and B11 confirmed the samples as alluvials. The samples from above bedrock from Hole B11 showed dolerite but no in situ samples were recovered from the lower part of Hole B9. Alluvials were found above bedrock in Hole B13, in Hole B20 and in the upper part of Hole B12.

EMBANKMENT MATERIALS

The soils resulting from the in situ decomposition of granite gneiss vary widely in properties according to the depth of weathering and to the nature of the original rock. At the ground surface, a fairly uniform laterite residual shows few characteristics of the underlying rocks and the differences due to changes in rock types becomes more apparent at depth. The weathering profile is shown in detail in Table 1, and it is apparent that in an area where there is 60 feet of weathered material above bedrock a great variety of soil types with their own characteristic properties is present. This means that different combinations of soils may be incorporated into an enbankment, but it also means that field control of excavation and mixing must be efficient.

The three main soil types are:

(i) laterite, gravels and clays up to 8 feet thick

(ii) gibbsite-kaolin clays up to 20 feet thick

(iii) residual quartz and mica-quartz phases, up to 20 feet thick.

Table 1

WEATHERING PROFILE OF GRANITIC ROCKS, DARLING RANGE

Geological Material	Definition	Engineering Properties	General Classification
Slopewash, sand, soil	Clayey, silty or sandy soil with no rock texture, the surface layer often containing roots and humus	Undesirable as foundation or borrow material	Soil
Pisolitic laterite	Spherical ironstone pebbles lightly cemented together with a lighter coloured earthy matrix	Permeable. Excellent source of borrow material	
Massive laterite	Strongly cemented ironstone, massive and concretionary	Permeable. If too strongly cemented, may be unsuited as borrow material	Laterite
Laterite-gibbsite	Yellow silty clay, minor laterite nodules	Permeable. Good borrow material	
Kaolin clay phase	Complete decomposition of granite by in situ weathering. Micas absent, feldspars decomposed to clays, some residual quartz grains	Impermeable. Clay type borrow material	
Ferruginated zone	Zone of fluctuation of groundwater level. Iron deposition may form a ' hard pan '	Permeable. Reasonable type of borrow material	Highly weathered granite
Quartz residual phase	Largely consists of quartz grains and some decomposed feldspars. Disintegrates into a mass of clayey sand when immersed in water	Permeable. Sandy type of borrow material	
Mica-quartz residual phase	Found above schistose rocks, amphibolites or micaceous banded gneiss. Micas are slightly weathered and form about 50% of the rock	Permeable. Undesirable as borrow or foundation material	
Moderately weathered granite gneiss	All the mineral components are present but are considerably altered. Strength is such that pieces of NX core cannot be broken in the hands	Largely impermeable. Difficult to excavate readily	Moderately weathered granite
Slightly weathered granite gneiss	Granite distinctly weathered throughout the fabric of the rock as shown by slight limonite staining	Impermeable, water movement in some joints. Unsuited as borrow or rock-fill material	Slightly weathered granite
Fresh granite gneiss with limonite stained joints	Joint faces coated or stained with limonite, but the rock between is unweathered	Leakage through joints. Suitable as rock-fill material	Fresh granite, stained joints
Fresh granite gneiss	Unweathered granite. Possible joint coatings include chlorite, calcite, pyrites and clay	Leakage in joints. Suitable as rock-fill material	Fresh granite

As these may be regarded as layers largely parallel to the present land surface, they can be excavated either selectively and placed in different zones of the dam or excavated together and blended into a single material with intermediate properties. If the latter method is adopted then excavation of the borrow by means of inclined slices, or working borrow pits at different levels, will be necessary.

The only undesirable material of the laterite sequence is the cemented massive laterite that may be difficult to reduce to an acceptable size. The thickest development and strongest cementation of the laterite occurs on the valley slopes at the edge of the residual cover. In other words a borrow pit should not be sited on a valley slope but rather in the flatter interfluves or plateaux where the massive laterite layer is thin or even absent.

As well as the considerable vertical variations that exist in the soil types and their properties, the changing mineral character of the granite gneiss complex imposes differences in a lateral direction. The residual soils developed from a highly schistose or micaceous parent rock are of particular significance, as they are undesirable in every engineering aspect when in the mica-quartz residual phase (Table 1). These soils should not be used in embankment construction because they are usually semi pervious, often partially saturated, and of low cohesion caused by lubricated mica flakes.

SITE APPRAISAL

BEARING QUALITY OF THE FOUNDATION

The relatively narrow, asymmetric valley of Wungong Brook at the upper site is characteristic of river valleys in the Darling Range: the north-eastern bank shows the effects of physical weathering (exfoliation sheets) while the south-western bank is mantled with a residual soil sequence resulting from the chemical weathering of a gneissic complex. There has been some alluviation of the valley, but there is little active erosion or deposition at present because of the underfit nature of Wungong Brook.

The major complication of the site appears to be the presence of a deeply weathered dolerite dyke on the right bank and crossing the stream bed. This dyke is of importance as the cut off trench will have to be upstream at all locations to avoid differential settlement of the clay core. Furthermore the strike of the dyke through the foundation area is of interest as one margin may be faulted. If this feature transects the foundation, deep excavation will be necessary to prevent leakage.

PERMEABILITY CHARACTERISTICS

In the residual soil profiles that are developed on granitic rocks in the Darling Range there are two permeable zones. Close to present ground surface the saprolite (laterite) sequence often retains a quantity of water from rainfall and run-off. Deeper percolation is hindered by the underlying kaolin clay.

Water movement is also possible beneath the kaolin clay layer, which forms the upper boundary of the fluctuating water table, with the top limits marked by a zone of deposition of iron minerals (Table 1). The completely weathered granite gneiss residual that forms the aquifer is mostly composed of quartz grains of sand size with minor kaolin and partly weathered feldspar minerals. Biotite, hornblende and feldspar have been largely broken down and removed by chemical and physical forces.

These two zones, which are usually separated by more than 20 feet of relatively impermeable clay, have considerable engineering signifiance for the construction of a dam at the Wungong Brook upper site. It is considered essential that the rolled earth core on either abutment should be founded below the laterite zones, in impermeable kaolin clay. On the lower valley slopes where the weathering sequence is less than 20 feet thick, the core zone should be founded on slightly weathered granite gneiss, below the clay and quartz residual zones.

In the relatively unweathered granite gneiss and dolerite rocks that will form the foundation in the valley bottom, water movement will be mainly controlled by a few major openings. This is because the rocks are impermeable and many of the joints are discontinuous, as shown by comparing the geological logs with the water pressure test results. This means that the stop grouting method, using a packer to isolate areas showing imperfections disclosed during drilling, would be advantageous, as the mix and pressure best adapted for connecting the particular fracture can be employed in each case. However, the possible presence in D.D.H. 1 of fractures that would allow the grout to bypass the packer means that the stop grouting method may not be completely effective. If the stage method was used the seams and joint filling materials in the weathered zone of the rock may not be sufficiently cleaned by pressure washing to provide a good grout bond, and the grout would break back through previously sealed seams. There would then be no certainty that the lower zones were subjected to full pressures. Accordingly a combination of the two methods may be most effective. This would include grouting to the full depth of the first zone by stage grouting methods, then cleaning the hole and drilling the first stage of the second zone, and grouting this stage with an expandable packer. When refusal is reached the packer is removed and a grout connection made to the grout nipple set as the surface of the core trench. This procedure, first employed at Folsom Dam, overcomes the problem of surface leakage, and allows full pressure to be applied at any depth.

RESERVOIR PERMEABILITY

Because of the confinement of the reservoir in the lower part of a deep valley, the place where leakage is most likely to occur is through the foundation area of the dam. Major joint systems, in particular exfoliation joints, and the sheared margins of dolerite or amphibolite 'dykes' are possible leakage channels. A grout curtain drilled from the floor of the core trench will be necessary to prevent water movement. It is recommended that on the northern valley slopes the grout holes should be drilled at right angles to the ground surface in order to intersect the exfoliation joints at minimum depth.

CONCLUSIONS

1. The final stage of investigation will involve the drilling of auger holes about 50 feet apart, along the cut-off line from one side of the valley to the other. This will complete the feasibility stage of exploration.

2. Adequate foundation for an earthfill dam should be readily obtainable at the upper site. The complications caused by the presence of dolerite dykes striking across Wungong Brook in the vicinity of the trial line and along the left bank can be overcome by shifting the cut-off wall upstream to clear the cross channel dyke.

3. All the older and recent alluvials in the valley bottom will need to be removed to allow a satisfactory cut-off to be obtained, and on the valley slopes the core trench should be taken down below any signs of lateritization.

4. A grouting programme should be designed to intersect a few water-bearing fractures of large capacity; it is recommended that a combination of stop and stage grouting methods should be employed, with the holes on both abutments directed at right angles to the ground surface.

5. Adequate supplies of borrow material are available in the immediate vicinity of the dam site. Care will be necessary in excavation of the borrow pits to ensure adequate mixing of the various types of weathered material making up the soil profile.

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GEOLOGICAL INVESTIGATIONS AT THE ORD RIVER MAIN DAM SITE No. 2 IN 1964

By

F. R. Gordon

ABSTRACT

The most economic and sound engineering solution for a dam type at the Ord River Main Dam Site No. 2 is a rockfill dam, located about 250 feet downstream of the site of the concrete gravity dam, previously investigated in detail. The geological setting of the site was established by a special study of regional geology and tectonics. Detailed geological mapping of the site was basic to the investigations, and exploration consisted of five diamond drill holes, dozer costeans, hand trenches and auger drilling in the river bed.

In the foundation area the bedrock topography and the distribution of rock types, especially the location of a tectonically disturbed contact between quartzite and phyllite, was of critical importance to design work. Detailed information was also obtained from diamond drilling on joints, faults and permeability. The structure of the spillway area was established by mapping supplemented by drilling and trenching, thus allowing maximum stability to be achieved in shape and position.

The information obtained in 1964 completed the design stage of investigation.

INTRODUCTION

Three types of dam were considered possible at the No. 2 Dam Site on the Ord River:

(1) A rockfill embankment with a clay core and a saddle spillway.

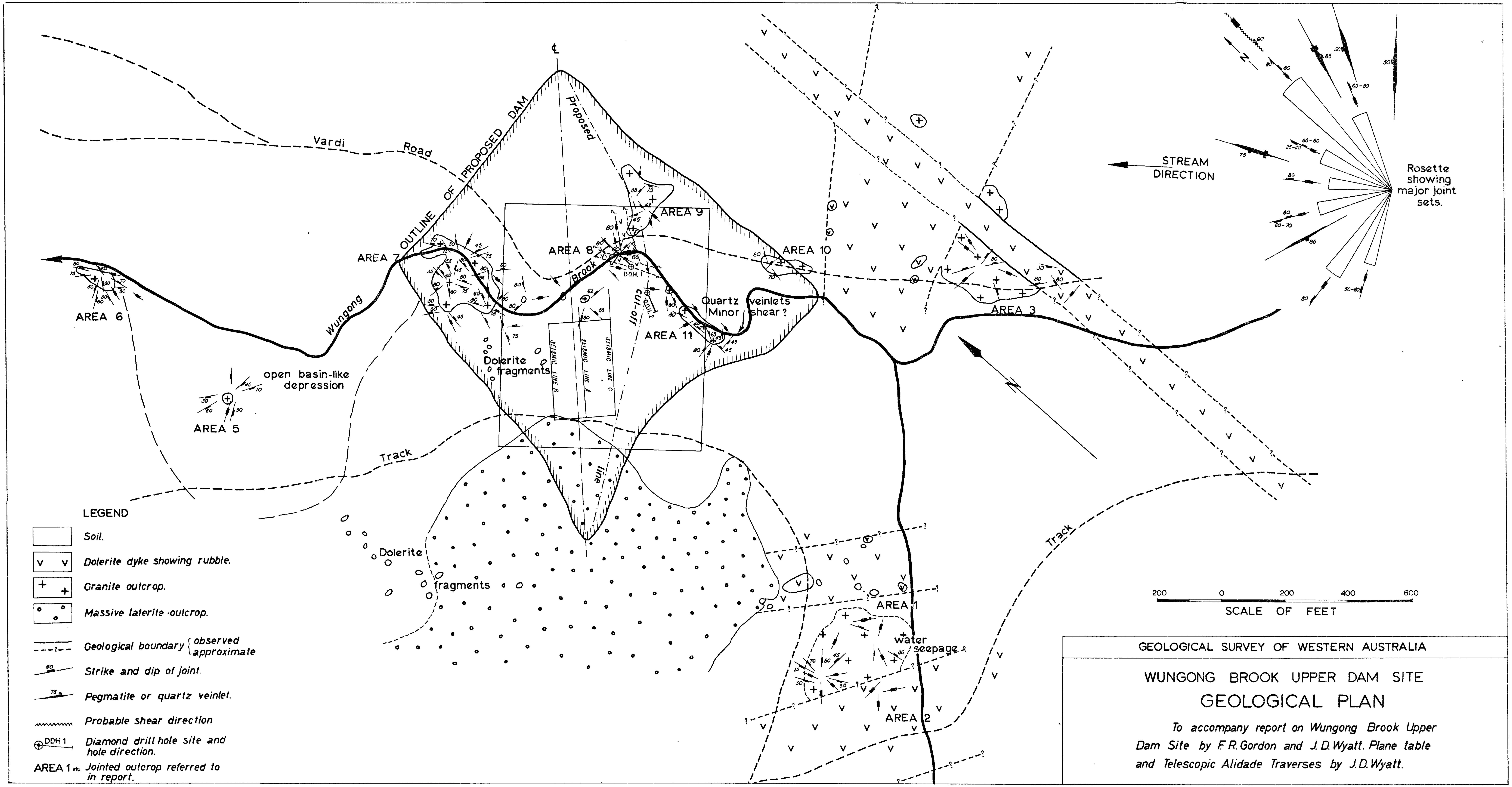
(2) A solid concrete gravity dam with a central ogee spillway.

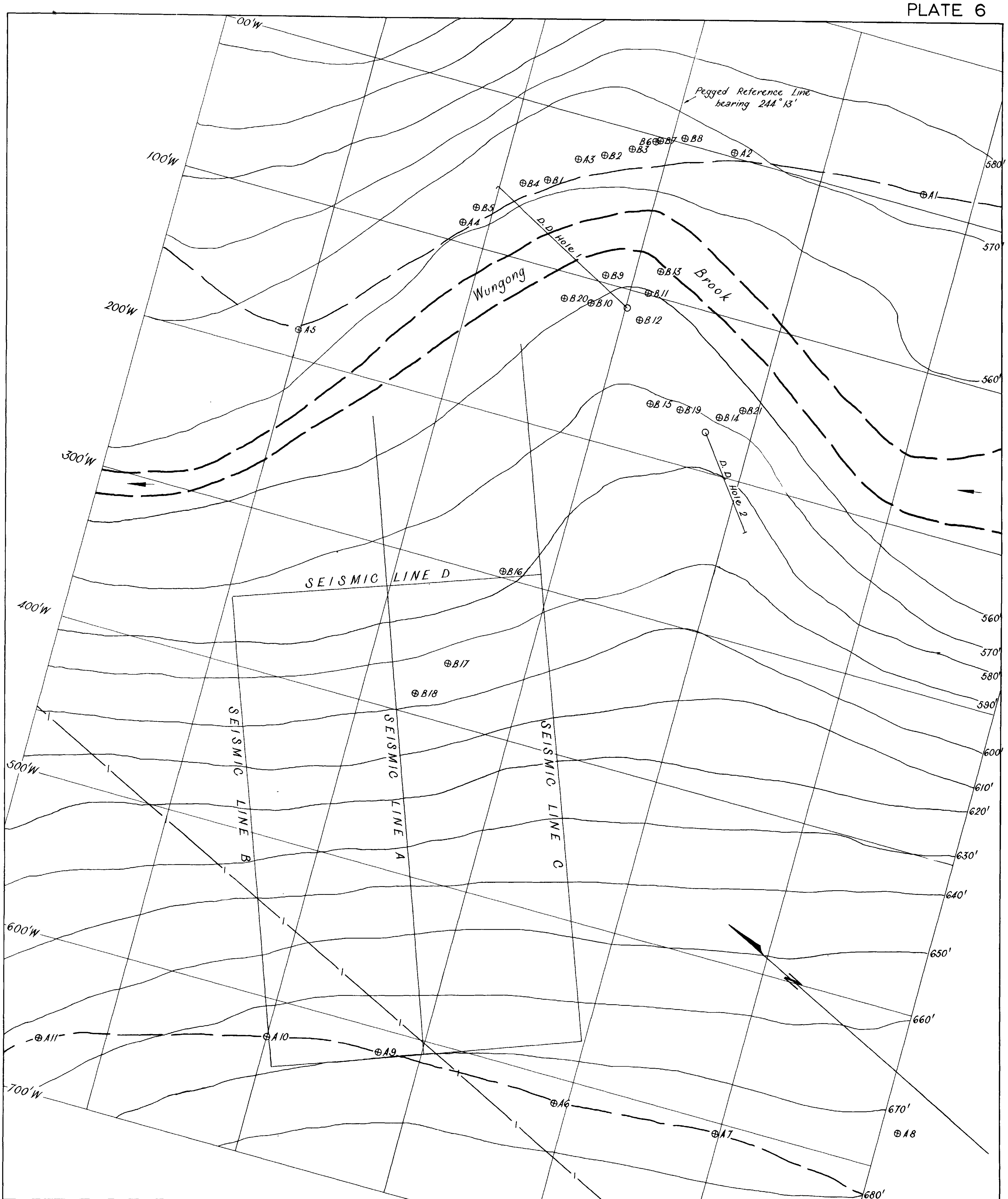
(3) A hollow gravity dam.

Detailed engineering analysis has indicated that the most economical solution is a rockfill dam, 220 feet above lowest foundation, with a channel spillway 200 feet deep by 450 feet wide. Equally important, the serious problem of stability of the quartzite rock cap on the left abutment (Gordon, 1962) is lessened with a rockfill dam, as the clay core can be located downstream on phyllite underlying the quartzite capping (Lewis and Webster, 1964).

The final basis of investigation for feasibility of the structure concerned a rockfill dam with a centreline located 250 feet downstream of the centreline of the gravity dam investigated in considerable detail in 1961-63.

The change of location meant that further detailed geological mapping was necessary. Also, it was considered that subdivision of the quartzite succession would greatly assist analysis and design of a proposed underground power station. The entire area of the dam site was mapped by plane


GEOLOGICAL SURVEY OF WESTERN AUSTRALIA
WUNGONG BROOK UPPER DAM SITE
GEOLOGICAL PLAN
To accompany report on Wungong Brook Upper Dam Site by F. R. Gordon and J. D. Wyatt. Plane table and Telescopic Alidade Traverses by J. D. Wyatt.
LEGEND
Soil.
Dolerite dyke showing rubble.
Granite outcrop.
Massive laterite outcrop.
Geological boundary { observed approximate
Strike and dip of joint.
Pegmatite or quartz veinlet.
Probable shear direction
DDH 1 Diamond drill hole site and hole direction.
AREA 1 etc. Jointed outcrop referred to in report.
200 0 200 400 600
SCALE OF FEET
Rosette showing major joint sets.
STREAM DIRECTION
OUTLINE OF PROPOSED DAM
Proposed cut-off line
Vardi Road
Track
Wungong Brook
AREA 1
AREA 2
AREA 3
AREA 5
AREA 6
AREA 7
AREA 8
AREA 9
AREA 10
AREA 11
Quartz veinlets
Minor shear ?
Dolerite fragments
open basin-like depression
Water seepage
SEISMIC LINE A
SEISMIC LINE B
SEISMIC LINE C
D.D.H. 1
D.D.H. 2



REFERENCE

—— / —— /	FENCE
○—— D.D. hole 2	DIAMOND DRILL HOLE, INCLINED
⊕ A2	AUGER HOLES (1962)
⊕ B10	AUGER HOLES (1964)
— — — —	TRACKS

FEET 50 40 30 20 10 0 50 100 150 200 FEET

SCALE

GEOLOGICAL SURVEY OF WESTERN AUSTRALIA

WUNGONG BROOK UPPER DAM SITE

TOPOGRAPHY AND SITE EXPLORATION

table and telescopic alidade traverses at a scale of 50 feet to an inch by J. D. Wyatt in the period May to August 1964 (Wyatt, 1965).

Although a geological setting to the scheme was available from the work of the joint Bureau of Mineral Resources/West Australian Geological Survey party on the Mt. Brooking 1-mile Sheet in 1963, a more detailed picture of the area surrounding the dam site was needed for the interpretation and evaluation of the tectonic features studied in close detail on the site. Accordingly in October 1964, R. C. Horwitz mapped the geology and tectonic features of an area of approximately six square miles centred on the main dam site (Horwitz, 1964).

Prior to 1964, 27 diamond drill holes and two adits had been used to obtain foundation data, but very little information was available from this exploration concerning the foundation area of the rockfill dam and the structure of the spillway channel. The investigations done in 1964 included three diamond drill holes in the river bed and two drill holes in the spillway area, along with dozer costeans and hand trenches in the same area (Plate 7). Shingle supplies in the river channel upstream of the dam site and core material in the flat, upstream of the dam site (Coolibah Pocket) were explored with dozer cuts. Supervision of the diamond drilling and allied investigations was provided by E. E. Swarbrick in the period August to November 1964 (Swarbrick, 1965 b).

DETAILED GEOLOGY

The geology of dam site area was mapped by J. D. Wyatt at a scale of 50 feet to an inch, and part of this work at a reduced scale is shown in Plate 7. A stratigraphic column showing the individual beds defined in the phyllite quartzite succession by Wyatt (1965) is given in Table 1. This division into beds of similar lithologic properties is artificial in that the rocks in the area belong to one cycle of deposition; boundaries are therefore not always clearly recognisable, and lateral and vertical variations in rock type occur. However, in the restricted area of the dam site, this division has allowed a more precise appreciation of the engineering properties of the rocks as applied to the various structures.

The basal beds of the cyclothem are an orthoquartzite with minor pebble horizons grading upwards into a sequence of variably bedded sandstone with minor siltstone layers. These pass transitionally into predominantly silty sandstone and then into siltstone beds with occasional sandy lenses. Metamorphism of these beds has produced the phyllitic quartzite sequence, as exposed on the northern abutment.

Table 1

STRATIGRAPHIC COLUMN—ORD RIVER MAIN DAM SITE No. 2

Age	Stratigraphy	Description	Thickness	Informal Name
QUATERNARY		Recent deposits of silt, sand and shingle. Poorly sorted, bedded, lenticular	feet Approx. 60	Alluvium
		Recent soil and talus material	10	Scree
UPPER PROTEROZOIC	LISSADELL FORMATION	Siltstone-sandstone sequence, fine-grained, grey to red-brown, thin-bedded, flaggy. Restricted mainly to the eastern side of Blind Gully Fault. Not studied in detail	Over 1,000	Coolibah Quartzite
		Silty sandstone, fine to medium-grained, red-brown thin-bedded. High silt-size content	150 to 180	Spillway Quartzite
		Sandstone with minor silty partings. Alternating thick and thin beds of sandstone with fine siltstone interbeds. Medium-grained, red-brown to grey. Beds generally thicker than underlying member	80 to 120	Hilltop Quartzite
		Sandstone with common thin-bedded silty sandstone beds. Fine to medium-grained, white to beige	90 to 105	Scree Slope Quartzite
		Sandstone with minor pebble bed horizons. Medium to coarse-grained, well-bedded, red to pink-brown. Altered to softer sandstone in upper section	100 to 120	Pebble Bed Quartzite
		Orthoquartzite, massive, medium to coarse-grained, white to fawn. Lateral transition into Pebble Bed Quartzite noted in some left abutment outcrops	50 to 260	Right Abutment Quartzite
	GOLDEN GATE SILTSTONE	Siltstone, thinly-bedded, fine-grained, red-brown to grey-green. Contains minor sand lenses. Outcrop form varies on either side of the Ord River	Over 250	Spillway Phyllite

Three major faults with throws in excess of 100 feet were recorded during the detailed mapping of the site:

1. *The Blind Gully Fault* is an arcuate, normal fault, with an apparent vertical throw of 1,000 feet maximum, east side down on a trend of 015°. It is arcuate because of later folding in places. No engineering structures are directly affected by this feature.

2. *The Spillway Fault* strikes about easterly and dips normally at 45° to the south. A throw of some 700 feet, south block down, has been measured. This fault strikes approximately along the centre line of the spillway channel at floor level, and is of dominant structural importancec.

3. *The Power Station Fault* has been postulated by J. D. Wyatt as having a vertical displacement of about 100 feet; it strikes easterly, with

a normal movement, and dips at 82° to the north. An alternative suggestion (Swarbrick, 1965b) that this is, in fact, a wrench fault, appears to offer a simpler explanation.

Numerous faults of small magnitude have resulted in considerable modifications to the topography of the dam site.

EXPLORATION

Two diamond drill holes were drilled in the river bed in order to close the gap left by previous investigations in the lowest part of the floor. In addition the holes were designed to determine the trend of the phyllite—quartzite contact, and to give an idea of the thickness of quartzite below the river bed. These objectives were achieved with D.D.H.s 28 and 29, and some implications of the drilling results are discussed separately in this Annual Report (Swarbrick, 1965b).

Jetting which failed to penetrate gravel layers, was followed by extensive drilling with a Gemco auger drill in the foundation area of the dam; this resulted in a complete modification of ideas on the depth of alluvium in the river bed and the configuration of bedrock. Depths of as much as 96 feet to solid rock were recorded, and even these figures may be increased if boulders are present, as is quite likely, in the deeper troughs. Plunge pool erosion in phyllite immediately downstream of a bar of massive quartzite is suggested to account for the abrupt changes in bedrock topography.

D.D.H. 33M was positioned near the centre of the proposed outdoor power station, and was drilled at a depression of 33° in an upstream direction to test the foundation rock and to determine the position and nature of the Power Station Fault zone. The power station will be founded on well laminated and bedded, red-brown and pink quartzite and sandstone with beds of hard blue quartzite. The rock is considerably broken by shears, minor crush zones, and open cavities, and a programme of consolidation grouting will be essential to prevent foundation settlement. Intersections with the Power Station Fault and probably with Fault No. 13 were obtained, and the nature of the brecciated zone in each case as well as the succession of rock types suggest that these faults are transcurrent. This reassessment of the Power Station Fault, previously considered normal, is of significance to the structural picture of the river bed.

Water pressure tests were carried out in all three river bed holes, using a Treifus packer. Tests were carried out at 10-foot intervals during drilling. Considerable and consistent water losses showed that the Right Abutment Quartzite contains numerous open fractures, and that an extensive grouting programme would be necessary to prevent seepage.

The production of a detailed geological map of the spillway area, especially the localization and estimation of dip of the Spillway Fault, allowed the placement of diamond drill holes in positions of maximum effectiveness. D.D.H. 32M was collared in Costean No. 2, and was designed to intersect the Spillway Fault close to spillway floor level. Micaceous flaggy siltstone with fine-grained muddy sandstone and minor pale green shale of the Spillway Quartzite were encountered down to 164 feet hole depth, and below the probable intersection of the Spillway Fault, dark grey-green to black mudstone and siltstone of the Spillway Phyllite were cored to the completion of the hole.

The second spillway hole (31M) which was drilled from the saddle, was located to make a shallow intersection with the Spillway Fault and to assess the physical condition of the rock in the spillway cutting. Intersection with the Spillway Fault and Fault No. 2 allowed a clear picture of the stability of the north side of the spillway.

Three dozer costeans were cut in the spillway area, and further hand trenching was carried out to extend these and to aid the mapping of geological boundaries.

The concentration of work in the spillway channel area was necessary because of the lack of results obtained from the earlier drilling (Holes 9M, 16M, 17M, 27M). The present concept of the spillway structure is of beds dipping to the north at about 20 degrees with a normal fault displacement of about 700 feet, south block down, on the Spillway Fault. Block gliding in the Right Abutment Quartzite in a southerly direction has meant displacement of the upper portions of the fault.

CONCLUSIONS

Because of a change in the location and type of dam, the extensive drilling investigations of previous years were not of direct relevance to the present proposed rockfill dam.

Detailed geologic mapping, set within a defined regional framework of geology and tectonics, was of value in locating the drill holes of a limited drilling programme.

Previous concepts concerning the topography of the river bed were considerably revised after the use of a Gemco drill in place of water jetting. The accurate definition of the shape and nature of the river bed will not be known however until alluvium has been removed during construction. The contact between massive quartzite and phyllite, which in places is marked by mechanical breakdown of the phyllite, is of importance in the foundation area of the dam. The unconformable contact has been studied in some detail and is explained by the mechanism of gravitational gliding (Swarbrick, 1965a).

Water pressure testing of the diamond drill holes in the river bed has confirmed previous ideas as to the need for a full grouting programme.

The exploration of the spillway channel has produced a rational picture that previously was lacking, and will allow the spillway to be positioned in a setting of maximum stability.

The 1964 investigations have completed the feasibility stage and much of the design stage of exploration. If the scheme is not proceeded with, it will not be for lack of foundation data.

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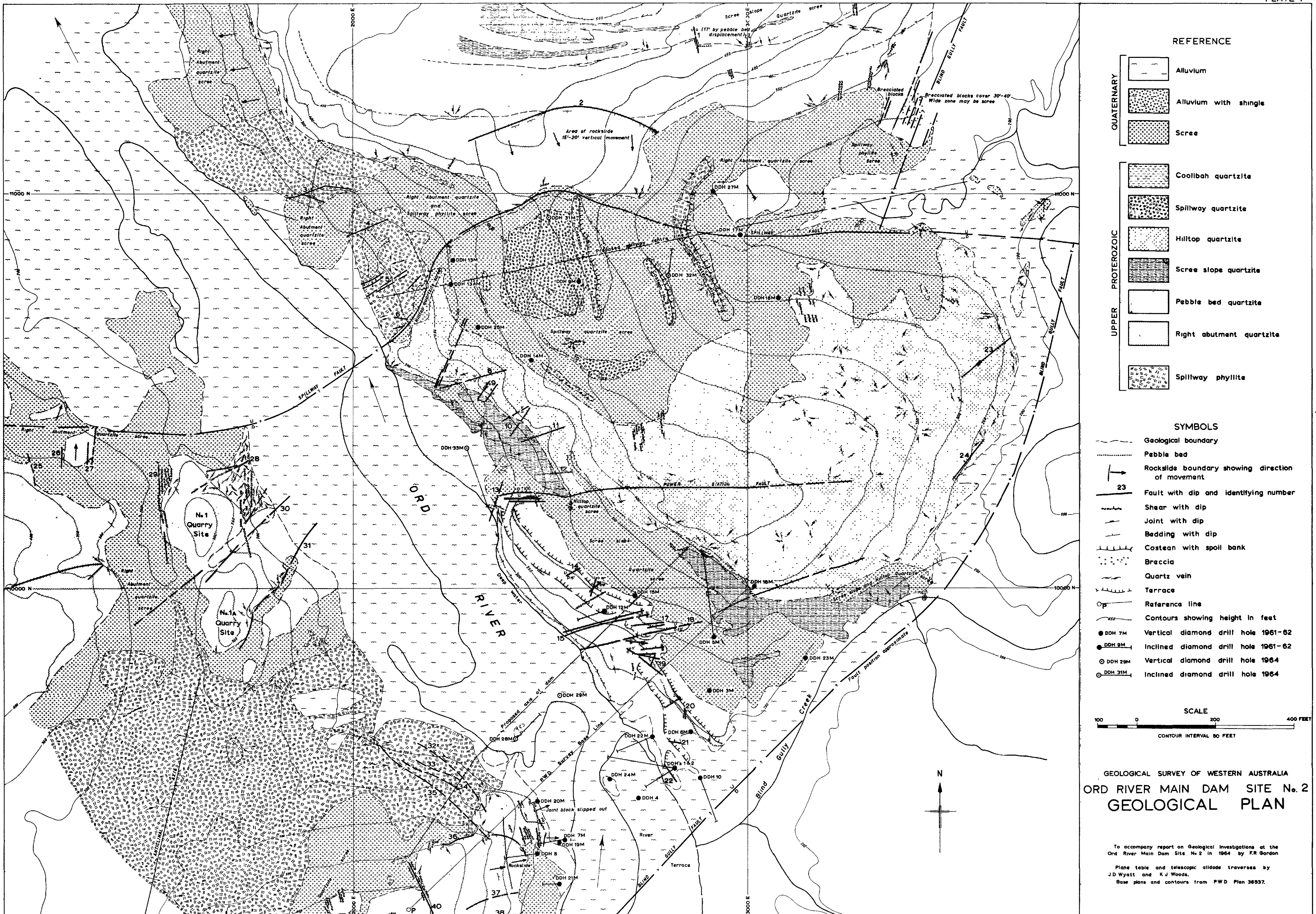
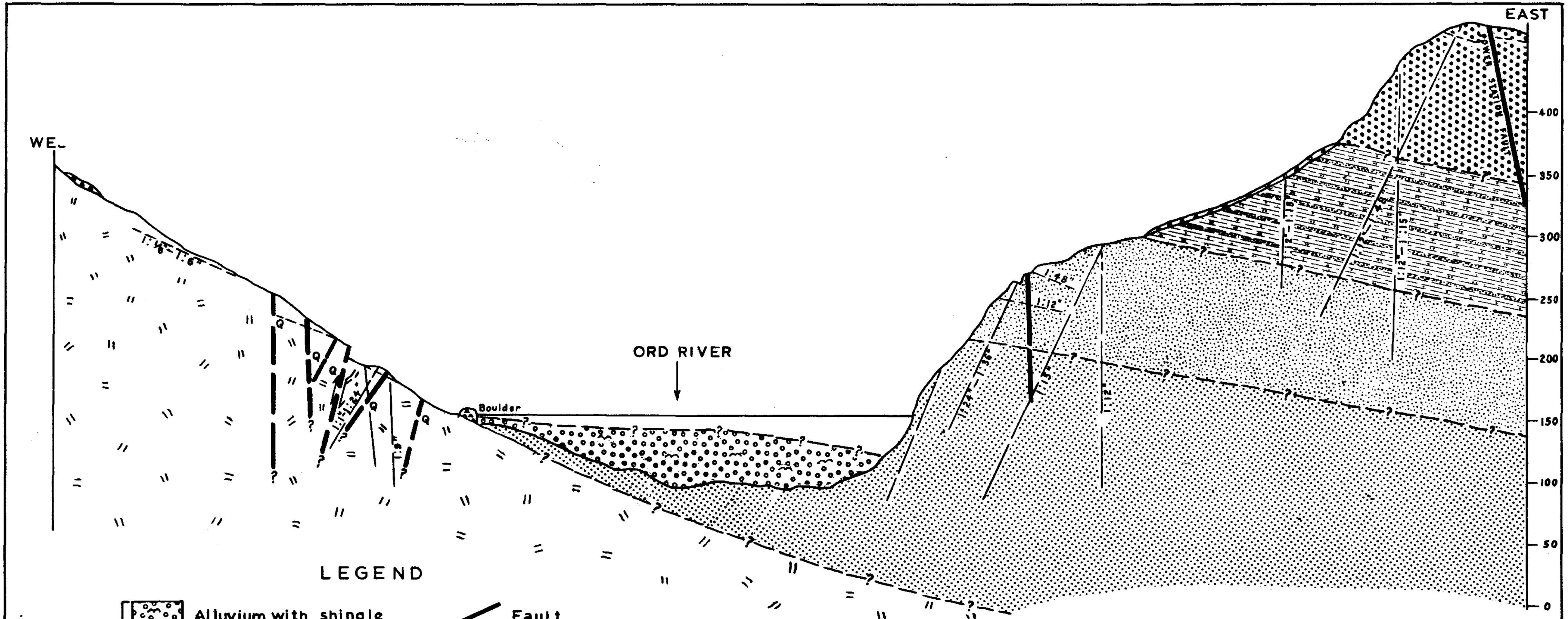
GRAVITATIONAL GLIDING TECTONICS AT THE ORD RIVER MAIN DAM SITE No. 2

by E. E. Swarbrick

ABSTRACT

Gravitational gliding in Proterozoic sediments is suggested to explain certain structures in the area of the Ord River Main Dam Site No. 2. Evidence is presented which supports a theory that movement has occurred between a thick quartzite sequence and a mudstone—siltstone succession. Considerable movement within the quartzite is also demonstrated. The origin of the movement is believed to lie in normal fault movement and differential erosion, in association with major wrench faulting.


REFERENCE
QUATERNARY
Alluvium
Alluvium with shingle
Scree
UPPER PROTEROZOIC
Coolibah quartzite
Spillway quartzite
Hilltop quartzite
Scree slope quartzite
Pebble bed quartzite
Right abutment quartzite
Spillway phyllite
SYMBOLS
Geological boundary
Pebble bed
Rockslide boundary showing direction of movement
Fault with dip and identifying number
Shear with dip
Joint with dip
Bedding with dip
Costean with spoil bank
Breccia
Quartz vein
Terrace
Reference line
Contours showing height in feet
Vertical diamond drill hole 1961-62
Inclined diamond drill hole 1961-62
Vertical diamond drill hole 1964
Inclined diamond drill hole 1964
SCALE
100
0
200
400 FEET
CONTOUR INTERVAL 50 FEET
GEOLOGICAL SURVEY OF WESTERN AUSTRALIA
ORD RIVER MAIN DAM SITE No. 2
GEOLOGICAL PLAN
To accompany report on Geological Investigations at the Ord River Main Dam Site No 2 in 1964 by F.R. Gordon
Plane table and telescopic alidade traverses by J.D. Wyatt and K.J. Woods.
Base plans and contours from PWD Plan 36537.
ORD RIVER
SPILLWAY FAULT
POWER STATION FAULT
BLIND GULLY FAULT
Blind Gully Creek
No 1 Quarry Site
No 1A Quarry Site
Area of rockslide 15'-20' vertical movement
Proposed axis of dam
Proposed spillway centre line
PWD Survey Base Line
Right Abutment quartzite scree
Spillway quartzite scree
Joint block slipped out
Rockslide
Deep water
River Terrace
Fault position approximate
Brecciated blocks cover 30'-40' Wide zone may be scree
11000 N
10000 N
2000 E
3000 E
N



GEOLOGICAL SURVEY OF WESTERN AUSTRALIA

ORD RIVER MAIN DAM SITE No. 2
GEOLOGICAL CROSS SECTION ON PROPOSED AXIS OF DAM

To accompany report by F. R. Gordon 1964

P.W.D. Theodolite survey with taped geological boundaries

Natural scale of feet

100 50 0 100 200 300

PLATE 8

8285

INTRODUCTION

The information presented in this report represents part of the work carried out during geological investigations at the Ord River Main Dam Site No. 2 in 1964. Further details of the geology are given by Wyatt (1965).

The dam site lies 30 miles upstream from the township of Kununurra and approximately 10 miles west of the junction of the main roads from Darwin and Nicholson Station to Kununurra. The surrounding area is one of variable relief, with fairly deep gorges downstream from the dam site and high level alluvial plains upstream.

In the dam site area Proterozoic sediments overlie quartz porphyries of the Whitewater Volcanics and porphyritic granite of the Lamboo Complex (Dunnett and Plumb, 1964). The Proterozoic sequence is given below:

Dunnett and Plumb (1964)	*Wyatt (1965)*
Lissadell Formation	Coolibah Quartzite Spillway Quartzite Hilltop Quartzite Scree Slope Quartzite Pebble Bed Quartzite Right Abutment Quartzite
minor unconformity	
Golden Gate Siltstone	Spillway Phyllite*

Subdivisions of part of the Lissadell Formation erected by Wyatt (1965) are not formal names. The sequence has been subdivided on a lithological basis for the purposes only of the work on the dam site. The names have been capitalised to avoid confusion with various features of the dam site which have similar names.

The Right Abutment Quartzite is a massive orthoquartzite up to 250 feet thick. Succeeding quartzite units have an increasing proportion of fine-grained material, and show a general tendency towards fine grain and thin bedding. Between the Right Abutment Quartzite and the Spillway Phyllite there is a minor unconformity which probably originated as a hiatus in sedimentation, but has since been complicated by gliding movement.

Structurally the area around the dam site is fairly simple. Folding is minor and is not considered pertinent to the subject of this report. There is a general dip to the northeast. Faulting is extensively developed, characteristically of a generally competent succession, and shows both normal and wrench movement. A tectonic map of the area is given in Plate 9.

Two major faults dominate the structural pattern of the area. The Blind Gully Fault (Plate 9) trends north-northeast along the eastern edge of the area and has a maximum displacement down to the east of 1,000 feet. This is considered to be the oldest fault in the area and is parallel to an ancient major lineament (the Halls Creek Mobile Zone) which occurs 4 to 5 miles to the east. Cutting and displacing the Blind Gully Fault is the Spillway Fault which trends east-northeast. This also is a normal fault with a maximum throw down to the south of 800 feet, although as will be shown later, it was initially a major wrench fault. Numerous other faults are present but are not considered relevant to the particular subject under discussion (see Plate 7).

GRAVITATIONAL GLIDING OF THE LISSADELL FORMATION

Evidence will be brought to indicate that the nature of the Right Abutment Quartzite/Spillway Phyllite interface should be considered in terms of what De Sitter (1956) calls "Gravitational Gliding Tectonics." Bedding plane slip is a commonly observed phenomenon in most layered sequences which are folded or tilted. There is considerable evidence however, to suggest that between the Spillway Phyllite and Right Abutment Quartzite, and also between different units of the Right Abutment Quartzite, there has been gravity-induced movement totalling hundreds of feet.

EVIDENCE OF MOVEMENT

The various points of evidence are grouped by occurrence within a particular structure or stratigraphical unit (Spillway Phyllite, Blind Gully Fault Zone, etc.). For ease of reference to locality of occurrence the various points are numbered consecutively with small Roman numerals irrespective of groupings. Corresponding numerals are shown in the appropriate locality on Plate 9.

Structural Features of the Quartzite/Phyllite Interface

North of the Spillway Fault the quartzite/phyllite interface dips approximately east of 10° to 25°. The dip of the rock units above and below the interface is approximately the same, but the strikes of the two units frequently differ, that of the quartzite being consistently 5° to 20° farther to the east than that of the phyllite. The interface is rarely seen as a plane, but more usually as a gap up to 12 inches wide separating the two units probably as a result of selective weathering.

On the left abutment the unconformity varies locally in nature, probably as a result of complication by movement similar to gravitational sliding. The interface is well exposed on the downstream edge of the block and can be followed continuously from near river level to the summit of the left abutment (Wyatt, 1962, fig. 6). Various structures are seen at the interface as one follows it up the hill.

(i) A quartzite fold, 36 inches in amplitude and 4 to 12 inches in wave-length protrudes down into the underlying Spillway Phyllite (see Plate 10a). The axial plane of the fold is parallel to the quartzite/phyllite interface and dips at 45° on a bearing of 095°. The fold is in the form of a tight syncline overturned to the west. Between the fold and the overlying quartzite the phyllite is tightly folded and plastically deformed.

(ii) Close to the fold is a large lenticular quartz vein in Spillway Phyllite up to 3 feet long and 4 inches thick. Phyllite laminae are dragged into and truncated by the vein. The vein generally dips at 20° on a bearing of 140° but approaching the interface changes to a steeper dip.

(iii) The interface immediately east of the fold is locally vertical, with the quartzite apparently gouging into the phyllite. In such cases the quartzite is brecciated, partly recrystallised, and striated parallel to the dip of the interface.

(iv) Farther up the hill, two blocks of massive quartzite are separated by a 4-inch wide gap which opens downwards into the interface (see Plate 10b). The gap is filled with thin-bedded, intensely sheared quartzite and mudstone.

Structures within the Spillway Phyllite

The intensity of deformation of the phyllite is closely related to that of the interface and lowest horizons of the quartzite. Thus north of the Spillway Fault the only structures in the phyllite are occasional small-scale symmetrical similar folds and minor box folds with basal shear, all with northerly trends. In the left abutment the phyllite is deformed into a series of small drag folds generally overturned to the east (Wyatt, 1962, fig. 5). In Quarry Site No. 1 (see Plate 9) the interface is not exposed. The lowest units of the Right Abutment Quartzite are intensely deformed (see below), and the phyllite close to the probable position of the interface is isoclinally folded on north-south axes, with axial planes dipping west.

Structures within the Right Abutment Quartzite

(v) The most distinctive structures in the quartzite are planes here called planes of detachment (Gordon, 1963, figs. 1, 4). These are highly polished and, although occasionally parallel to the bedding, generally cut across it at low angles.

* The use of the term "phyllite" by Wyatt is petrologically incorrect, but on this project has become accepted by usage, and will be used here for ease of definition. The sequence to which it is applied is in fact, a sequence of mudstone and siltstone with some thin quartzite near the top.

Furthermore, the dip is generally 5 degrees to 10 degrees farther to the east than that of the bedding. The planes dip at angles ranging from 10 degrees to 45 degrees, and show numerous and often rapid changes of dip. Occasionally the unit above the plane has in it a cavity up to 24 inches high immediately above the plane, which is probably caused by weathering of the intensely jointed quartzite (Wyatt, 1962, fig. 7). The planes of detachment are considered to result from movement of the quartzite above them down the dip of the plane. These planes are often parallel to the ground surface and could be interpreted as exfoliation planes. They are not typical of such planes in that (a) they are highly polished and (b) they control the other joint and fracture system of the quartzite. Exfoliation planes are usually a late phenomenon and as such are frequently controlled by other jointing.

(vi) A characteristic feature of the quartzite is the development of a major sheet-jointing which dips consistently west at angles from 50 degrees to 85 degrees. Typically the sheeting is best developed above the planes of detachment occurring in the quartzite (Wyatt, 1962, fig. 7). The dip and strike of the sheeting appears to be more closely related to the attitude of the planes described later than to bedding.

(vii) The lowest horizons of the quartzite south of the Spillway Fault are often intensely deformed, and accompanied by well developed quartz veining. Quartz veining is common throughout the Lissadell Formation and usually shows a cause-and-effect relationship with the joint pattern in having a controlled frequency and orientation. The basal units of the quartzite in Quarry Site No. 1 however, show quartz veins developed to a degree that is uncharacteristic. The veining forms an anastomosing system with random orientation, in which the quartzite appears as rounded to subrounded masses in a vein-quartz matrix (Plate 10c). Similarly extensive development of vein quartz is found in various outcrops of the basal quartzite units.

(viii) In the extreme southwest of the dam site area, the quartzite outcrop is crossed by a zone of intense deformation. Extensive sheets of quartzite, with a northerly strike, are probably bedding units which have been lifted into near-vertical attitudes, and sharply flexed on horizontal axes (Plate 10d). These folds closely resemble the "cascade" folding described in association with gravitational gliding by Harrison and Falcon (1936) and are probably caused by steepening of the glide plane to the west. Cutting the whole sequence is a well developed series of vertical northerly-trending shear planes in a zone which is approximately 250 feet wide and is gently arcuate. The zone is not seen in the Spillway Phyllite outcrop, but the trend of the zone is continuous with a long narrow gully which also trends north-south, and passes immediately west of Quarry Site No. 1 (Plate 9). Quarry Site No. 1, as described earlier, is a zone of intensive deformation of the quartzite. Furthermore the western side of the outcrop has well developed sheet jointing and shear zone systems. This all suggests that the zone of deformation to the south was once continuous northwards. Across the phyllite outcrop the zone is expressed physiographically by the gully.

Structures Within the Blind Gully Fault Zone

Various structures associated with the Blind Gully Fault cannot be explained by invoking the normal movement of the fault. Such structures are considered to be more easily understood relative to a west to east compressive movement resulting from gliding on a bearing of approximately 070°. The close association of such structures with the fault suggests that the movement of the faulting and that of the gliding were intimately associated. The various structures associated with the fault and relevant to the gliding theory are described below.

(ix) Immediately west (upthrow side) of the Blind Gully Fault north of the Spillway Fault (Plate 9) a zone of intensely brecciated quartzite extends to the west for 100 feet. Some of the brecciation, notably that occurring on planes or in units dipping east at 70° to 80°, is considered to be directly related to the fault movement. Other units of breccia are obviously more directly related to planes of detachment occurring within the quartzite. One such example is shown in plate 10c. The brecciated unit which is roughly 3 feet thick, lies above part of the plane of detachment which can be traced westwards for a considerable distance. At its western end the plane dips east at 35° to 40°. To the east this dip decreased to 10° to 15° then rapidly increases once more to 35° to 40° beneath the breccia. The western end of the unit (i.e. above the flat-lying part of the plane of detachment) is completely brecciated, as far as the point of flexure of the plane of detachment. At this point the degree of brecciation decreases by stages; thus the quartzite above that part of the plane which dips at 35° to 40° shows only intense sheet jointing which dips west and closely resembles the sheet jointing in the Right Abutment Quartzite as described earlier. The lowest part of the most intensely brecciated section of the unit is locally absent, the resulting cavity being clay-filled.

(x) Beds on the eastern (downthrow) side of the fault are overturned to the east parallel to the fault. South from the Spillway Fault the Blind Gully Fault can be traced to the east of the Right Abutment Block, thence southwards along the left bank of the river between outcrops of Right Abutment Quartzite to the west, and Spillway (?Coolibah) Quartzite to the east. These latter thin bedded sediments frequently show steepening and overturning of bedding. All the available evidence indicates that the Blind Gully Fault is a normal fault with an easterly throw and an easterly dipping fault plane. The youngest sediments occur consistently to the east and there is no evidence that the fault is a thrust or reverse fault. Movement on this fault therefore is unlikely to cause steepening of bedding to verticality and overturning, without invoking cylindrical fault planes or cylindrical joint systems. It is far more likely that the overturning is the result of intense compressive movement from west to east. No evidence of regional compressive folding of the nature exists, and it is considered that the structures result from gravitational gliding. Immediately west of the fault in these areas, the Spillway Phyllite is isoclinally folded, the westerly dipping axial planes also indicating west to east movement (Plate 10f).

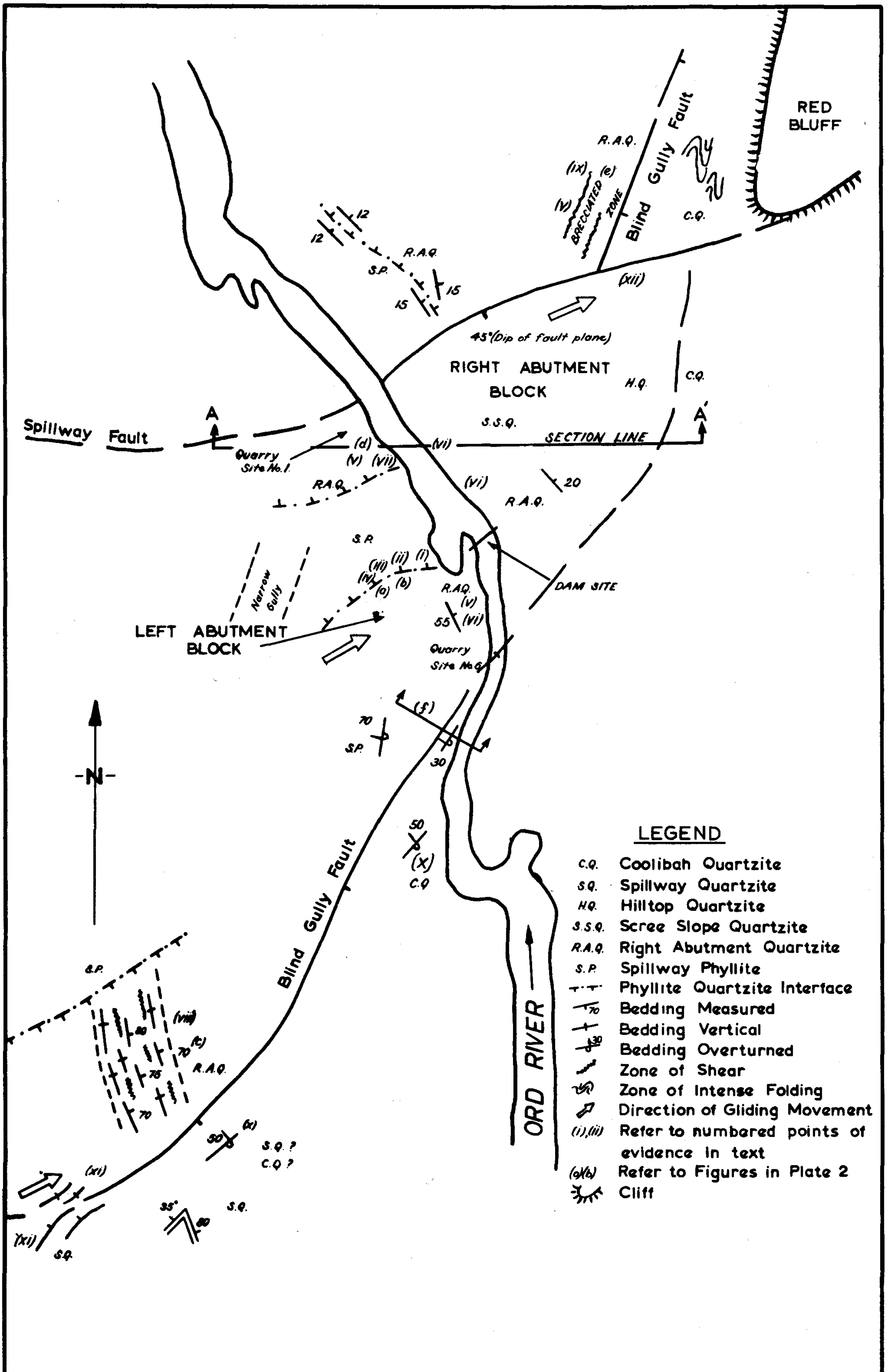
(xi) Bedding strikes are often fault controlled. In the extreme southwest of the area the Blind Gully Fault turns west, and bedding strikes in the Spillway Phyllite and Spillway Quartzite are dragged into the plane of the Blind Gully Fault, in a manner consistent with a dextral wrench movement on the fault (see Plate 9). The evidence suggests that in this area the fault plane is near-vertical, which is also consistent with wrench movement.

(xii) The Blind Gully Fault is anomalously displaced by the Spillway Fault. As stated above, the Blind Gully Fault is a normal fault dipping east, and the Spillway Fault is a normal fault dipping south. Any displacement of the Blind Gully Fault by the Spillway Fault therefore should be in a dextral sense. The displacement however, is some 500 feet to the east, which is a sinistral movement (Plate 9). It is therefore suggested that the Blind Gully Fault has been displaced by the Spillway Fault both laterally and vertically.

ORIGIN AND NATURE OF THE GLIDING MOVEMENT

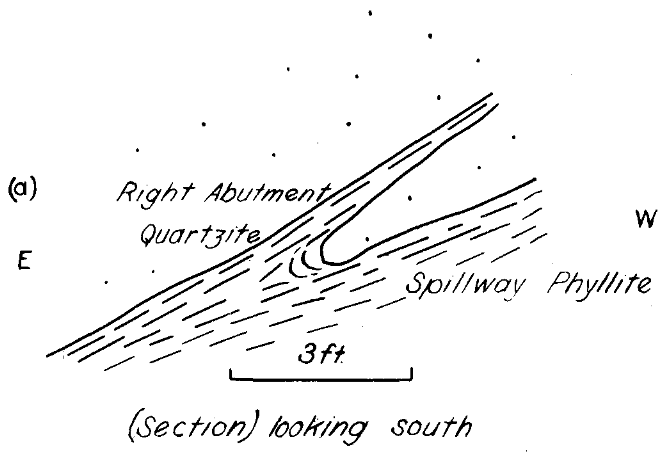
The easterly direction of gliding means that the movement was triggered in the eastern part of the area, and suggests it was related to movement on the Blind Gully Fault. The idea is supported by the intimate association of the fault with structures described earlier which are related to the fault but resulted from the gliding movement.

The trend and magnitude of the Blind Gully Fault are such that the easterly displacement would place the thin bedded Coolibah and Spillway Quartzites in juxtaposition with the massive Right Abutment Quartzite over a considerable length of the fault. Differential erosion would

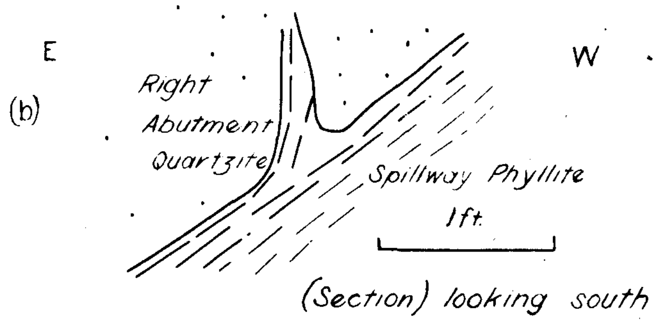


ORD RIVER MAIN DAM SITE No. 2

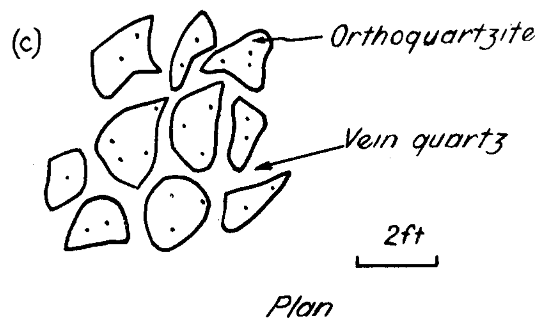
TECTONIC MAP



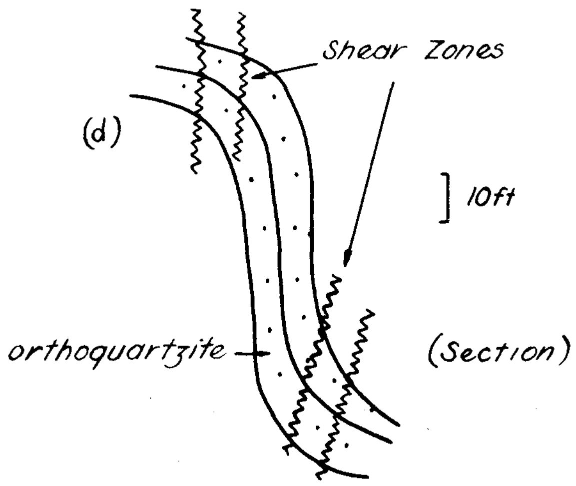
(a) Orthoquartzite fold in Spillway Phyllite



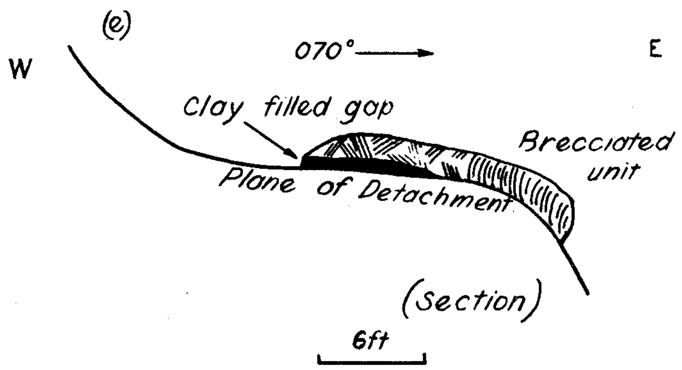
(b) Spillway Phyllite injected into orthoquartzite



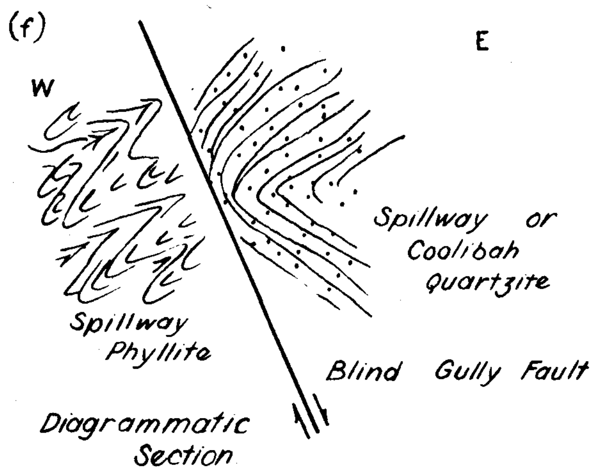
(c) Isolated masses of orthoquartzite in vein quartz



(d) Cascade folding and vertical to near vertical shear in Orthoquartzite



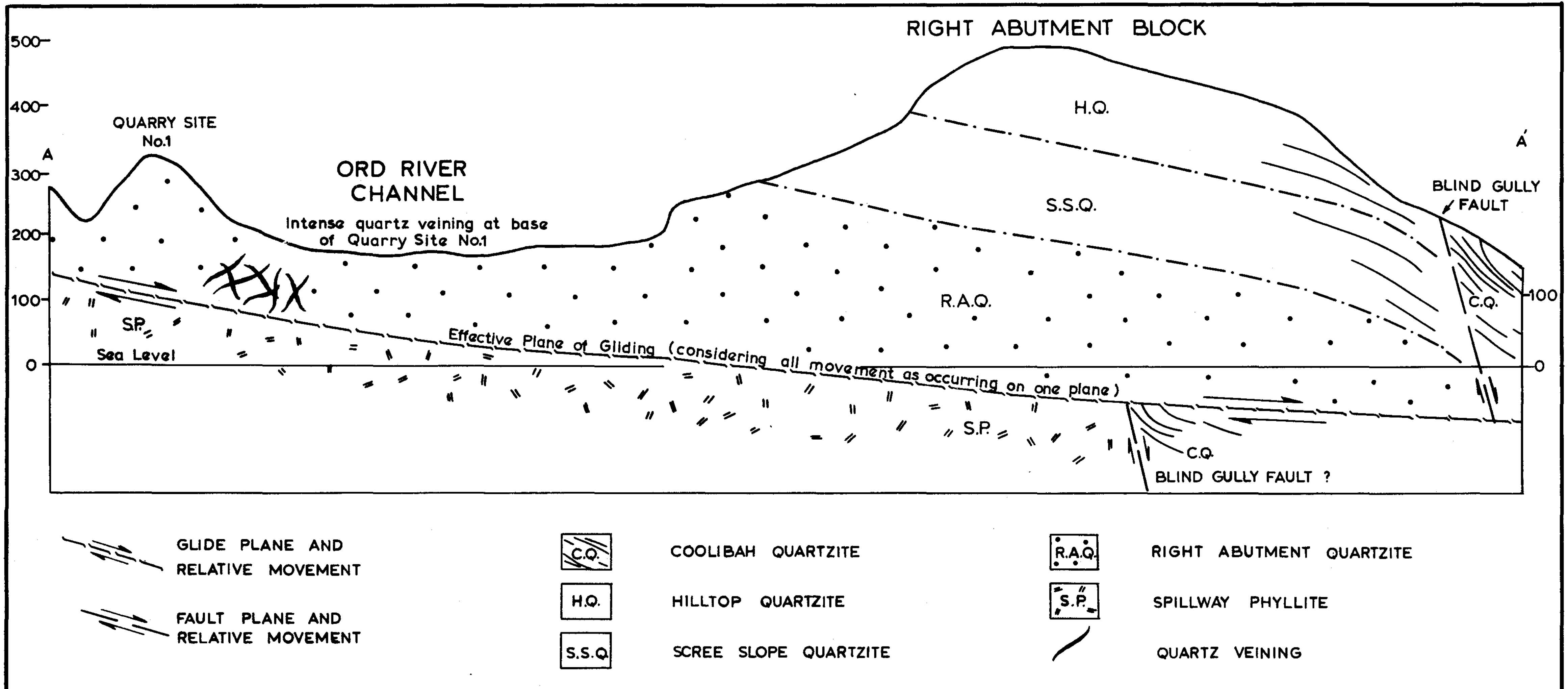
(e) Brecciated orthoquartzite above a flexured plane of detachment



(f) Isoclinal folding and overturning adjacent to the Blind Gully Fault

ORD RIVER MAIN DAM SITE No 2

SKETCHES (a-f) SHOWING OBSERVED GEOLOGICAL FEATURES



GEOLOGICAL SURVEY OF WESTERN AUSTRALIA

ORD RIVER MAIN DAM SITE No.2

GEOLOGICAL SECTION A – A′

Scale of feet

200 0 200 400

$\frac{H}{V}=1$

8655

PLATE 11

then tend to remove the thin bedded younger sediments, leaving the quartzite upstanding and unsupported on the western side of the fault. This situation coupled with the easterly regional dip was ideal for the promotion of gravitational gliding.

The Spillway Phyllite/Right Abutment Quartzite interface would be the most likely plane on which movement would be initiated. Certainly some movement has taken place on that plane, as shown by the structures on the interface and small-scale folding of the phyllite below the interface. The amount of movement indicated by the intensity and preservation of these structures however, is not consistent with the observed lateral displacement of at least 500 feet of the Blind Gully Fault. It is possible that wrench movement has taken place on the Spillway Fault independently of the gliding movement, but even so there is incontrovertible evidence that a certain amount of movement took place purely within the Right Abutment Quartzite. Why planes of weakness (planes of detachment) should develop independently of bedding, so close to the supposedly weak quartzite/phyllite interface, is not clear. It is possible that the quartzite beds at the top of the Spillway Phyllite gave sufficient resistance to the phyllite sequence. Whatever mechanism operated, considerable movement took place on each plane of detachment. As a result the planes became highly polished and the units above the planes were intensely sheet jointed. One of the more spectacular results of the movement within the quartzite is the zone of cascade folding and vertical shear occurring 1½ to 2 miles southwest of the dam site as described earlier.

The Blind Gully Fault is virtually the easterly limit of the gliding movement. In the Right Abutment Block however, that part of the fault above the glide plane or planes has been carried eastwards. Thus below the glide plane the Blind Gully Fault continues with its original trend subject only to relatively minor displacement by the vertical throw of the Spillway Fault (Plate 11).

Much of the relief of stress was taken up by the wrench movement of the Spillway Fault, and also of the southerly part of the Blind Gully Fault. These two faults therefore define the major part of the glide mass and are virtually its northerly and southerly limits. North of the Spillway Fault the quartzite has not moved very far to the east, possibly because of the presence of a resistant sandstone mass known as the Red Bluff. (It may be significant to the location and origin of the Spillway Fault, that the easterly extension of the fault passes close to the southern end of the Red Bluff). However, although very little movement occurred north of the fault, the compressive forces operating were similar to those in areas to the south. This is shown by intense folding of the Coolibah Quartzite between the fault and the Red Bluff. As no relief of stress could be obtained by movement therefore, the area became one of intense brecciation. The parts most intensely brecciated would be those underlain by a flat-lying plane of detachment. Some movement would occur, but insufficient for the relief of stress, and the result would be intense brecciation. Where the plane of detachment dipped fairly steeply to the east however, the unit above would be protected to a certain extent, and the intensity of deformation thus relatively decreased (see Plate 10e).

Following its initial wrench movement, which was in response to the gliding movement, the Spillway Fault became the focal plane for the relief of stress set up by later movement, and which resulted in a southerly downthrow in a vertical sense. This final vertical movement is documented by the presence on the fault plane of striae which dip parallel to the dip of the fault plane.

CONCLUSIONS

It is considered that the various structures described from the area of the dam site are the result of a gravitational gliding movement from west to east initiated by movement on the Blind Gully Fault. The gliding was not limited to a single plane but occurred on a number of planes within the quartzite and also at the quartzite/phyllite interface. One of the major effects of the movement was to displace the Blind Gully Fault to the east, mainly along the Spillway Fault. Beneath the lower limit of the glide block therefore, the Blind Gully Fault should be found more or less in its original position, only slightly displaced by the vertical movement on the Spillway Fault (Plate 11). This portion of the fault, below the glide block could be uncovered to the west of its present mapped position when the dam site is excavated.

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THE SEARCH FOR OIL IN WESTERN AUSTRALIA IN 1964

by P. E. Playford

INTRODUCTION

The most important developments in the search for oil in Western Australia since the Rough Range oil strike in 1953 occurred during 1964. Oil and gas were discovered at Yardarino in the Perth Basin and at Barrow Island in the Carnarvon Basin. The commercial potential of each of these fields was still being evaluated at the end of the year. One oil and gas well and another gas well had been completed at Yardarino and three oil and gas wells at Barrow Island.

The amount of geophysical work and test drilling increased considerably in 1964 as compared with 1963, and exploratory work was carried out in all sedimentary basins except for the Ord Basin. Six oil-test wells were completed in the Carnarvon Basin, five in the Perth Basin, and two in the Bonaparte Gulf Basin. At the end of the year one oil-test well, Barrow No. 4, was still being drilled in the Carnarvon Basin, and another, Gingin No. 1, in the Perth Basin.

Two stratigraphic wells were drilled in the Perth Basin and another in the Eucla Basin. Geophysical operations totalling some 60 party months of seismic work (including 1.7 months of marine seismic surveys), and 39 party months of gravity work were conducted in the Perth, Carnarvon, Canning, Bonaparte Gulf and Officer Basins. Surface geological mapping was undertaken in the Perth, Carnarvon, Canning and Officer Basins.

OIL HOLDINGS

The positions of Permits to Explore and Licenses to Prospect in Western Australia at the end of 1964 are shown on Plate 12. Details regarding each permit and license are shown on the following table:

OIL HOLDINGS IN WESTERN AUSTRALIA ON 31/12/64

Permits to Explore

No.	Name of Holder	Area in Square Miles	Date of Expiry of Current Tenure
27H	West Australian Petroleum Pty. Ltd.	34,650	31/12/65
28H	do. do. do.	30,750	31/12/65
30H	do. do. do.	140,200	31/12/65
106H	Westralian Oil Ltd.	11,800	28/9/65
127H	Alliance Oil Development Australia N.L.	13,800	28/3/65
134H	Exoil Pty. Ltd. and Hunt Petroleum Corporation	12,600	Appln. pending
135H	do. do. do.	12,600	do.
136H	do. do. do.	12,450	do.
142H	Hawkstone Oil Co. Ltd.	5,200	8/4/65
147H	Hunt Oil Co. and Placid Oil Co.	12,850	16/8/65
148H	do. do. do.	12,600	16/8/65
151H	Hackathorn Oils Pty. Ltd.	14,200	7/2/65
152H	do. do.	11,650	7/2/65
153H	do. do.	13,050	7/2/65
156H	Hunt Oil Co. and Placid Oil Co.	12,450	10/7/65
157H	do. do. do.	12,600	10/7/65
158H	do. do. do.	12,800	10/7/65
159H	do. do. do.	12,800	10/7/65
161H	do. do. do.	12,900	24/8/65
172H	Alliance Petroleum Australia N.L.	6,150	30/7/65
173H	do. do. do.	12,250	30/7/65
174H	do. do. do.	6,100	30/7/65
175H	do. do. do.	6,050	30/7/65
177H	do. do. do.	6,050	30/7/65
178H	Australian Oil Corporation	12,300	28/2/65
193H	Hawkstone Oil Co. Ltd.	2,750	5/8/65
199H	Pilbara Exploration N.L.	11,950	15/2/65
205H	Alliance Petroleum Australia N.L.	16,700	17/9/66
206H	do. do. do.	12,950	17/9/66
207H	do. do. do.	13,000	17/9/66
209H	Australian Oil Corporation	12,200	28/2/65
210H	do. do.	12,050	28/2/65
211H	do. do.	5,975	28/2/65
213H	Woodside (Lakes Entrance) Oil Co. N.L.; B.O.C. of Aust. Ltd.; Shell Development (Aust.) Pty. Ltd.	103,700	20/6/65
216H	Pilbara Exploration N.L.	13,200	10/4/65
217H	West Australian Petroleum Pty. Ltd.	17,600	30/5/65
221H	Australian Aquitaine Petroleum Pty. Ltd.; Arco Ltd.	44,000	28/7/66
225H	West Australian Petroleum Pty. Ltd.	7,500	20/7/66
226H	do. do. do.	34,700	6/4/66
227H	do. do. do.	11,400	6/4/66
228H	do. do. do.	2,900	13/5/66
231H	Great Southern Oil Co. Pty. Ltd.	15,376	9/10/66
232H	Victorian Oil N.L.	3,000	10/9/66
233H	West Australian Petroleum Pty. Ltd.	34,650	17/12/66
235H	Tasman Oil Pty. Ltd.	29,500	17/12/66
236H	Abrolhos Oil N.L.; British Petroleum Co. of Aust.	2,300	17/12/66
237H	West Australian Petroleum Pty. Ltd.	8,950	Appln. pending

Licenses to Prospect

No.	Name of Holder	Area in Square Miles	Date of Expiry of Current Tenure
66H	West Australian Petroleum Pty. Ltd.	200	18/1/65
67H	do. do. do.	199·4	20/4/65
74H	do. do. do.	186	17/5/65
75H	do. do. do.	190·8	17/5/65
76H	do. do. do.	192·9	17/5/65
77H	do. do. do.	196·2	17/5/65
78H	do. do. do.	189·7	17/5/65
79H	do. do. do.	198·8	17/5/65
80H	do. do. do.	188·9	17/5/65
81H	do. do. do.	193·4	17/5/65
82H	do. do. do.	198·1	17/5/65
83H	do. do. do.	193·1	17/5/65
84H	do. do. do.	187·4	17/11/65
85H	do. do. do.	187	17/5/65
86H	do. do. do.	189	17/5/65
87H	do. do. do.	189	5/1/65
88H	Hawkstone Oil Co. Ltd.	189	28/2/65
90H	West Australian Petroleum Pty. Ltd.	160·5	27/2/65
91H	do. do. do.	133·8	27/8/65
94H	do. do. do.	186·5	27/2/65
96H	do. do. do.	100	18/9/65
97H	do. do. do.	191·4	26/7/65
99H	do. do. do.	190·5	4/12/65
101H	do. do. do.	193·6	17/12/65
102H	do. do. do.	195·6	13/1/65
103H	do. do. do.	200	20/5/65
104H	do. do. do.	197·9	6/6/65
105H	do. do. do.	196	14/8/65
106H	do. do. do.	200	11/9/65
107H	do. do. do.	200	25/2/66
108H	do. do. do.	200 (excl. Lyndon Loc. 42)	22/1/66
109H	do. do. do.	200	Appln. pending
111H	do. do. do.	150	4/6/66
113H	do. do. do.	200	10/5/66
114H	Alliance Oil Development Australia N.L.	67	27/10/65

Licenses to Prospect—*continued.*

No.	Name of Holder	Area in Square Miles	Date of Expiry of Current Tenure
115H	West Australian Petroleum Pty. Ltd.	200	5/11/66
117H	do. do. do.	200	10/9/66
118H	do. do. do.	120	29/9/66
119H	do. do. do.	200	Appln. pending
120H	Westralian Oil Ltd.	196	30/11/66
121H	Associated Freney Oil Fields N.L.	120	Appln. pending
122H	do. do. do.	113·4	do.
123H	do. do. do.	113·2	do.
124H	do. do. do.	112·5	do.
125H	do. do. do.	112·5	do.
126H	West Australian Petroleum Pty. Ltd.	200	do.
127H	do. do. do.	200	do.

During the year the following farm-out agreements were made: West Australian Petroleum Pty. Ltd. farmed out Permits 226H and 227H to Continental Oil Co. of Australia Ltd. and Australian Sun Oil Ltd., and Permit 228H to French Petroleum Co. (Australia) Pty. Ltd. and Australian Aquitaine Petroleum Pty. Ltd.; Alliance Petroleum Australia N.L. farmed out Permits 172H-177H to Outback Oil Co. N.L.; Hackathorn Oils Pty. Ltd. farmed out Permits 151H and 152H to Geosurveys of Australia Pty. Ltd.; Abrolhos Oil N.L. farmed out Permit 193H to B.P. Petroleum Development Australia Ltd.; Alliance Oil Development Australia N.L. farmed out Permit 127H to Anacapa Corp. and Tasman Oil Pty. Ltd.; and Woodside (Lakes Entrance) Oil Co. N. L. farmed out Permit 213H to B.O.C. of Australia Ltd., Shell Development (Australia) Pty. Ltd., California Asiatic Oil Co., and Mid-Eastern Oil N.L.

DRILLING

The positions of all wells drilled for petroleum exploration in Western Australia to the end of 1964 are shown on Plate 13. The following wells were drilled during the year:

PERMIT TO EXPLORE 27H

Permit to Explore 27H is held by West Australia Petroleum Pty. Ltd. and covers part of the Perth Basin. The company completed five oil-test wells (Wicherina No. 1 and Yardarino Nos. 1-4) in this permit area during 1964. Another test well, Gingin No. 1, was being drilled at the end of the year.

The first significant petroleum discovery in the Perth Basin was made in Yardarino No. 1 during 1964. It yielded flows of dry gas amounting to as much as 15 million cubic feet per day and small quantities of oil. Yardarino Nos. 2 and 4 produced only salt water, but Yardarino No. 3, situated ¼ mile south of the discovery well, produced up to 2,000 barrels of oil per day.

Details of the wells drilled during the year in this permit area are as follows:

Gingin No. 1

Type: Oil test.

License to Prospect: 115H.

Latitude and Longitude: 31° 08′ 32″ S., 115° 49′ 35″ E.

Elevation: Ground 649 feet, rotary table 665 feet.

Date commenced: November 16th, 1964.

Status: Drilling ahead at 9,270 feet on 31st December, 1964.

Mt. Hill No. 1

Type: Stratigraphic.

Latitude and Longitude: 29° 04′ 05″ S., 114° 58′ 53″ E.

Elevation: Ground 378 feet, Kelly bushing 383 feet.

Date commenced: November 8th, 1964.

Date completed: November 21st, 1964.

Total depth: 1,858 feeet.

Bottomed in: Lower Triassic.

Mungarra No. 1
Type: Stratigraphic.
License to Prospect: 119H.
Latitude and Longitude: 28° 51′ 02″ S., 115° 06′ 55″ E.
Elevation: Ground 625 feet, Kelly bushing 630 feet.
Date commenced: October 3rd, 1964.
Date completed: November 4th, 1964.
Total depth: 1,998 feet.
Bottomed in: Lower Permian.

Wicherina No. 1
Type: Oil test.
License to Prospect: 107H.
Latitude and Longitude: 28° 49′ 53″ S., 115° 14′ 19″ E.
Elevation: Ground 862 feet, derrick floor 874 feet.
Date commenced: February 14th, 1964.
Date completed: March 6th, 1964.
Total depth: 5,530 feet.
Bottomed in: Lower Permian.
Remarks: Dry.

Yardarino No. 1
Type: Oil test.
License to Prospect: 111H.
Latitude and Longitude: 29° 13′ 13″ S., 115° 03′ 10″ E.
Elevation: Ground 142 feet, derrick floor 154 feet.
Date commenced: April 7th, 1964.
Date completed: June 16th, 1964 (suspended).
Total depth: 7,800 feet.
Bottomed in: Lower Permian.
Remarks: Test of interval 7,485-7,526 feet Wagina Sandstone (Upper Permian) produced gas at a maximum rate of 15.31 MMCF/day. The gas consists of 97% methane with traces of higher saturated hydrocarbons and quantities of oil condensate (A.P.I. gravity 44 deg.) A production test of the perforated interval 7,558-7,568 feet through a ¼-inch choke yielded 2-3 MMCF/day of gas with slugs of oil and water.

Yardarino No. 2
Type: Oil test.
License to Prospect: 111H.
Location: 1 mile north, ½ mile east of Yardarino No. 1.
Latitude and Longitude: 29° 12′ 22″ S., 115° 03′ 38″ E.
Elevation: Ground 289.6 feet, derrick floor 301.6 feet.
Date commenced: July 8th, 1964.
Date completed: September 20th, 1964.
Total depth: 10,090 feet.
Bottomed in: Lower Permian.
Remarks: Showings of oil and gas recorded from the Wagina Sandstone, but testing produced only salt water with traces of oil and gas.

Yardarina No. 3
Type: Oil test.
License to Prospect: 111H.
Location: ¼ mile south of Yardarino No. 1.
Latitude and Longitude: 29° 13′ 27″ S., 115° 03′ 10″ E.
Elevation: Ground 136 feet, derrick floor 148 feet.
Date commenced: October 8th, 1964.
Date completed: November 27th, 1964.
Total depth: 8,857 feet.
Bottomed in: Lower Permian.
Remarks: Testing of the interval 7,514-7,544 feet in the Wagina Sandstone produced oil (A.P.I. gravity 35 deg.) through a ½-inch choke at a rate of 1,300 barrels/day. Later testing of the perforated interval 7,526-7546 feet through a ⅜-inch choke yielded oil at up to 2,000 barrels/day with varying amounts of gas and water. However, the oil flow declined substantially with prolonged testing, to less than 100 barrels/day.

Yardarino No. 4
Type: Oil test.
License to Prospect: 111H.
Location: ½ mile west, ¼ mile north of Yardarino No. 1.
Latitude and Longitude: 29° 13′ 03″ S., 115° 02′ 39″ E.
Elevation: Ground 131 feet, derrick floor 144.5 feet.
Date commenced: December 4th, 1964.
Date completed: December 30th, 1964.
Total depth: 8,168 feet.
Bottomed in: Lower Permian.
Remarks: Dry; minor showings of oil and gas.

PERMIT TO EXPLORE 28H

Permit to explore 28H is held by West Australian Petroleum Pty. Ltd. and covers the north-central part of the Carnarvon Basin. The company completed three dry oil-test wells (Learmonth No. 2, Paterson No. 1 and Quail No. 1) in this permit area during the year. Details of these are as follows:

Learmonth No. 2
Type: Oil test.
License to Prospect: 108H.
Latitude and Longitude: 22° 17′ 35″ S., 114° 03′ 48″ E.
Elevation: Ground 72 feet, derrick floor 83 feet.
Date commenced: January 22nd, 1964.
Date completed: March 5th, 1964.
Total depth: 6,137 feet.
Bottomed in: Upper Triassic.
Remarks: Dry; traces of gas observed in the Cretaceous sequence. This well encountered the first Triassic rocks to be found in the Carnarvon Basin.

Paterson No. 1
Type: Oil test.
License to Prospect: 85H.
Latitude and Longitude: 22° 27′ 34″ S., 113° 55′ 56″ E.
Elevation: Ground 320 feet, derrick floor 331 feet.
Date commenced: November 8th, 1963.
Date completed: January 16th, 1964.
Total depth: 7,500 feet.
Bottomed in: Jurassic.
Remarks: Dry; traces of gas and minor fluorescence observed in the Jurassic sequence.

Quail No. 1
Type: Oil test.
License to Prospect: 103H.
Latitude and Longitude: 23° 57′ 04″ S., 114° 29′ 57″ E.
Elevation: Ground 376 feet, derrick floor 388 feet.
Date commenced: May 19th, 1963.
Date completed: January 20th, 1964.
Total depth: 11,747 feet.
Bottomed in: Tumblagooda Sandstone (?Lower Silurian).
Remarks: Dry.

PERMIT TO EXPLORE 217H

Permit to Explore 217H is held by West Australian Petroleum Pty. Ltd. and covers the northern part of the Carnarvon Basin and the southwestern extremity of the Canning Basin. Most of the permit area lies offshore. During the year the first test wells were drilled in this area, on Barrow Island. This island is situated in the northern Carnarvon Basin on the crest of a large anticlinal structure developed in Tertiary limestones. The company completed three test wells on the island during the year and all were successful in finding oil and gas. The best flows were obtained from Barrow No. 1, which yielded up to 11 million cubic feet per day of wet gas with condensate and up to 985 barrels per day of oil. Barrow No. 4 was drilling ahead at the end of the year at a depth of 5,156 feet.

Details of the wells are as follows:

Barrow No. 1

Type: Oil test.

License to Prospect: 113H.

Latitude and Longitude: 20° 49′ 06″ S., 115° 38′ 38″ E.

Elevation: Ground 170 feet, derrick floor 181 feet.

Date commenced: May 7th, 1964.

Date completed: August 27th, 1964.

Total depth: 9,785 feet.

Bottomed in: Upper Jurassic.

Remarks: The following are the important test results from this well: Interval 6,176-6,206 feet produced up to 11 MMCF/day of wet gas with quantities of distillate (A.P.I. gravity 50.1°). Interval, 6,759-6,740 feet produced up to 460 barrels/day of oil (A.P.I. gravity 37.3°) through a ½-inch choke. Interval, 6,750-6,783 feet through perforations produced up to 985 barrels/day of oil (A.P.I. gravity 38.1°) through a ½-inch choke. Small amounts of oil were recovered along with large volumes of salt water from the interval 7,490-7,580 feet, tested through perforations. The oil and gas in the above tests was produced from Upper Jurassic sediments. Showings of oil and gas were also observed in the overlying Cretaceous sequence.

Barrow No. 2

Type: Oil test.

License to Prospect: 113H.

Location: ½ mile south, ½ mile west of Barrow No. 1.

Latitude and Longitude: 20° 49′ 40″ S., 115° 23′ 07″ E.

Elevation: Ground 154 feet, derrick floor 165 feet.

Date commenced: August 30th, 1964.

Date completed: October 31st, 1964.

Total depth: 7,640 feet.

Bottomed in: Upper Jurassic.

Remarks: The following are the important test results from this well: Interval 6,124-6,167 feet produced up to 10 MMCF/day of wet gas with some condensate (A.P.I. gravity 44.8°) through a ½-inch choke. Interval 6,196-6,205 feet produced 120 barrels/day of oil (A.P.I. gravity 38.2°) with 440 MCF/day of gas. Interval 6,198-6,210 feet produced 337 barrels/day of oil (A.P.I. gravity 36.1°) with 1.14 MMCF/day of gas and 2.28 barrels/day of fresh water.

Barrow No. 3

Type: Oil test.

License to Prospect: 113H.

Location: ½ mile south of Barrow No. 1.

Latitude and Longitude: 20° 49′ 22″ S., 115° 23′ 11″ E.

Elevation: Ground 154 feet, derrick floor 165 feet.

Date commenced: November 4th, 1964.

Date completed: December 11th, 1964.

Total depth: 7,250 feet.

Bottomed in: Upper Jurassic.

Remarks: The following are the important test results from this well: Interval 6,792-6,798 feet (through perforations) produced a mixture of 90% oil (A.P.I. gravity 44.3°) and 10% water at 300-400 barrels/day with a flow of gas amounting to 1.5-2.8 MMCF/day. Interval 6,738-6,748 feet (through perforations) produced up to 240 barrels/day of oil (A.P.I. gravity 39°) with a trace of water and 800 MCF/day of gas through a ⅜-inch choke.

Barrow No. 4

Type: Oil test.

License to Prospect: 113H.

Location: 1 mile south, ½ mile east of Barrow No. 3.

Latitude and Longitude: 20° 50′ 32″ S., 115° 23′ 05″ E.

Elevation: Ground 101 feet, derrick floor 112 feet.

Date commenced: December 15th, 1964.

Status: Drilling ahead at 5,156 feet in Cretaceous sediments on 31st December, 1964.

PERMIT TO EXPLORE 127H

Permit to Explore 127H is held by Alliance Oil Development Australia N. L. and covers the Western Australian part of the Bonaparte Gulf Basin. Two test wells were completed in this permit area during 1964. The second of these, Bonaparte No. 2, obtained the first flow of hydrocarbons in the basin. It yielded up to 1.54 million cubic feet per day of methane with small amounts of higher saturated hydrocarbons from the Lower Carboniferous Milligans Beds. Details of the two wells are as follows:

Bonaparte No. 1

Type: Stratigraphic test.

Latitude and Longitude: 15° 01′ 00″ S., 128° 44′ 30″ E.

Elevation: Ground 339 feet, Kelly bushing 355 feet.

Date commenced: July 18th, 1963.

Date completed: June 6th, 1964.

Total depth: 10,530 feet.

Bottomed in: Upper Devonian.

Remarks: Dry hole.

Bonaparte No. 2

Type: Stratigraphic.

License to Prospect: 114H.

Latitude and Longitude: 15° 05′ 07″ S., 128° 43′ 16″ E.

Elevation: Ground 383 feet, Kelly bushing 400 feet.

Date commenced: July 27th, 1964.

Date completed: October 15th, 1964.

Total depth: 7,008 feet.

Bottomed in: Lower Carboniferous.

Remarks: The following important drill-stem tests were run in the hole: Interval 4,712-4,819 feet yielded a maximum gas flow of 1.54 MMCF/day. Interval 4,694-4,760 feet yielded a maximum gas flow of 1.15 MMCF/day.

PERMIT TO EXPLORE 173H

Permit to Explore 173H is held by Alliance Petroleum Australia N. L. and covers part of the Eucla Basin adjacent to the South Australian border. The company drilled a stratigraphic well, Eucla No. 1, in this area during 1964. Details are as follows:

Eucla No. 1

Type: Stratigraphic.

Latitude and Longitude: 31° 52′ 15″ S., 128° 13′ 21″ E. (approx.).

Elevation: Ground 40 feet (approx.)

Date commenced: January 21st, 1964.

Date completed: February 24th, 1964.

Total depth: 728 feet.

Bottomed in: Precambrian granitic rocks.

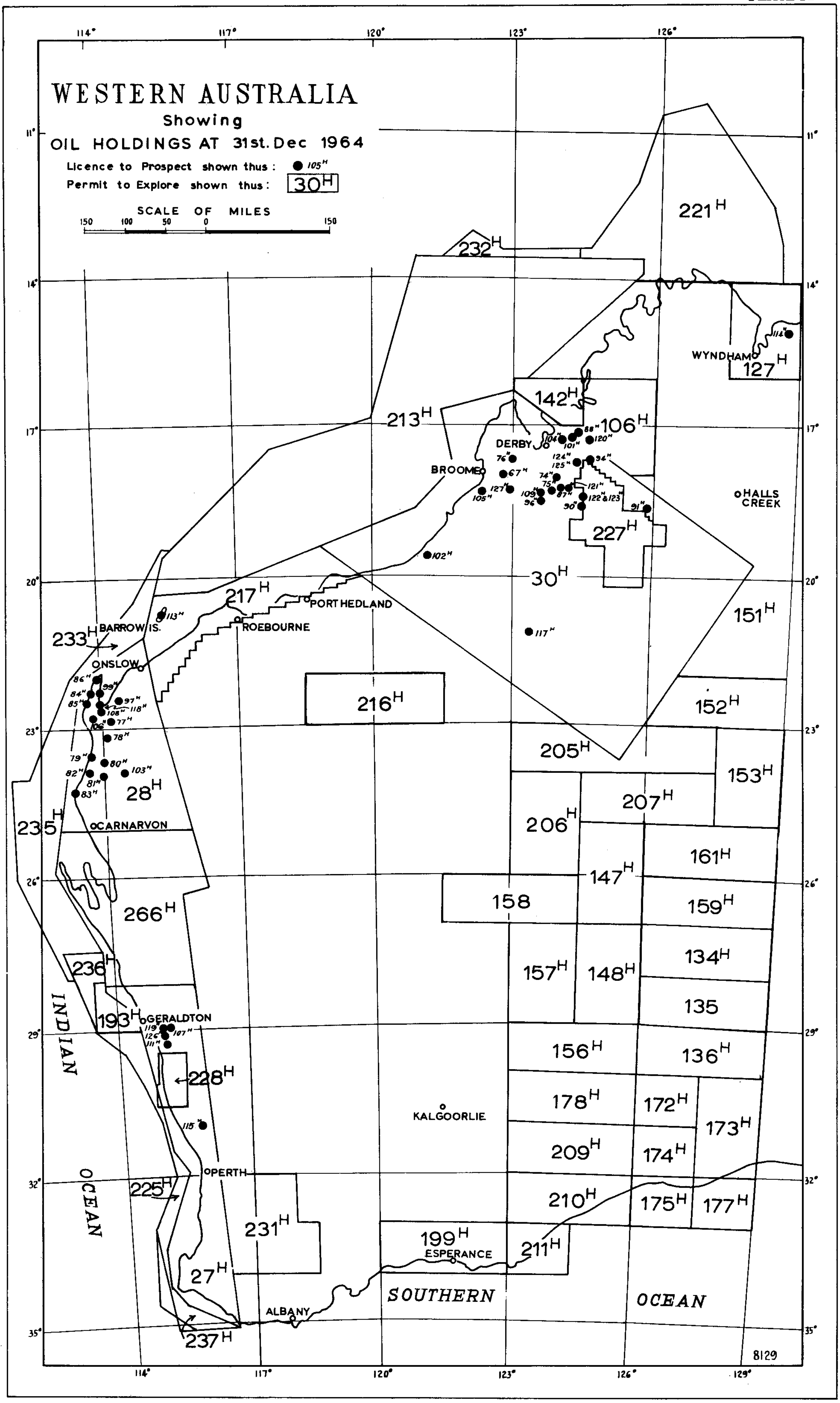
GEOPHYSICAL OPERATIONS

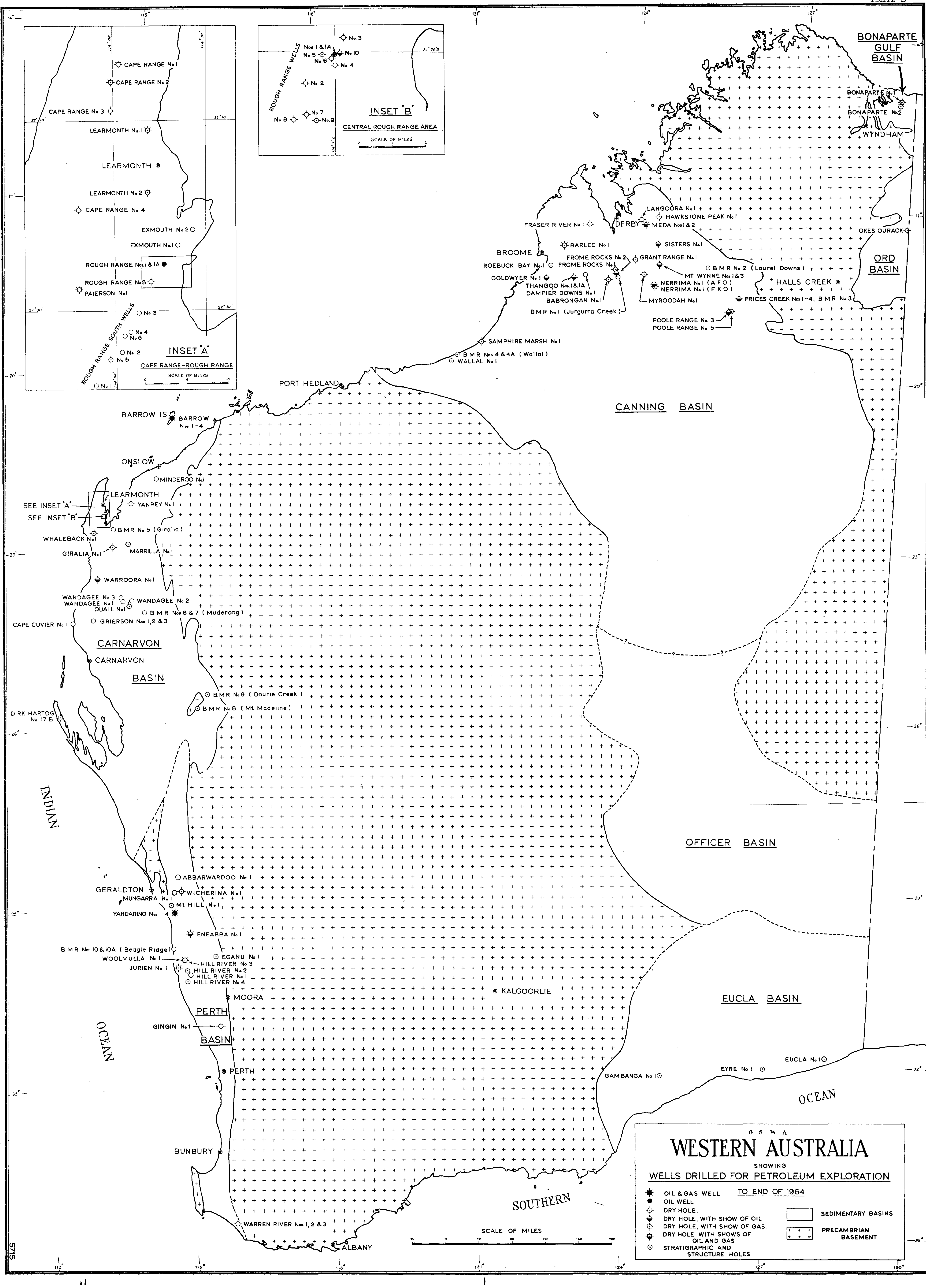
SEISMIC

During the year seismic operations were conducted in the Perth, Carnarvon, Canning, Bonaparte Gulf and Officer Basins. This work was distributed as follows:

Company	Permit	Basin	Party Months
West Australian Petroleum Pty. Ltd.	27H	Perth	17·8
Do. do. do.	30H	Canning	13·8
Do. do. do.	217H	Carnarvon	6·25
Continental Oil Co. of Australia Ltd.	226H	Carnarvon	6·5
Do. do. do.	227H	Canning	3·65
French Petroleum Co. (Aust.) Pty. Ltd.	228H	Perth	4·0
B.O.C. of Australia Ltd.	213H	Canning-Carnarvon (offshore)	1·7
Alliance Oil Development N.L.	127H	Bonaparte Gulf	2·5
Hunt Oil Co.	147H, 159H	Officer	4·0

PLATE 12


WESTERN AUSTRALIA
Showing
OIL HOLDINGS AT 31st. Dec 1964
Licence to Prospect shown thus : 105H
Permit to Explore shown thus : 30H
SCALE OF MILES
150 100 50 0 150
114° 117° 120° 123° 126° 129°
11° 14° 17° 20° 23° 26° 29° 32° 35°
221H
232H
213H
142H
106H
127H
WYNDHAM
DERBY
BROOME
HALLS CREEK
227H
30H
151H
217H
PORT HEDLAND
ROEBOURNE
BARROW IS.
233H
ONSLOW
216H
152H
205H
153H
207H
28H
206H
235H
CARNARVON
161H
147H
158
159H
266H
157H
148H
134H
236H
135
193H
GERALDTON
156H
136H
228H
178H
172H
173H
KALGOORLIE
209H
174H
PERTH
225H
210H
175H
177H
231H
199H
ESPERANCE
211H
27H
SOUTHERN
OCEAN
ALBANY
237H
INDIAN
OCEAN
8129


G S W A
WESTERN AUSTRALIA
SHOWING
WELLS DRILLED FOR PETROLEUM EXPLORATION
TO END OF 1964
OIL & GAS WELL
OIL WELL
DRY HOLE.
DRY HOLE, WITH SHOW OF OIL
DRY HOLE, WITH SHOW OF GAS.
DRY HOLE WITH SHOWS OF OIL AND GAS
STRATIGRAPHIC AND STRUCTURE HOLES
SEDIMENTARY BASINS
PRECAMBRIAN BASEMENT
SCALE OF MILES
INSET "A"
CAPE RANGE-ROUGH RANGE
INSET "B"
CENTRAL ROUGH RANGE AREA
CANNING BASIN
OFFICER BASIN
EUCLA BASIN
CARNARVON BASIN
PERTH BASIN
ORD BASIN
BONAPARTE GULF BASIN
INDIAN OCEAN
SOUTHERN OCEAN
BROOME
DERBY
PORT HEDLAND
ONSLOW
CARNARVON
GERALDTON
MOORA
PERTH
BUNBURY
ALBANY
KALGOORLIE
HALLS CREEK
WYNDHAM
BARROW IS
LEARMONTH
SEE INSET "A"
SEE INSET "B"
CAPE RANGE No 1
CAPE RANGE No 2
CAPE RANGE No 3
CAPE RANGE No 4
LEARMONTH No 1
LEARMONTH No 2
EXMOUTH No 2
EXMOUTH No 1
ROUGH RANGE Nos 1 & 1A
ROUGH RANGE No 8
PATERSON No 1
ROUGH RANGE SOUTH WELLS
ROUGH RANGE WELLS
BONAPARTE No 1
BONAPARTE No 2
LANGOORA No 1
HAWKSTONE PEAK No 1
MEDA Nos 1 & 2
FRASER RIVER No 1
OKES DURACK
BARLEE No 1
SISTERS No 1
FROME ROCKS No 2
FROME ROCKS No 1
GRANT RANGE No 1
B M R No 2 (Laurel Downs)
ROEBUCK BAY No 1
MT WYNNE Nos 1 & 3
NERRIMA No 1 (AFO)
NERRIMA No 1 (FKO)
GOLDWYER No 1
THANGOO Nos 1 & 1A
DAMPIER DOWNS No 1
BABRONGAN No 1
MYROODAH No 1
PRICES CREEK Nos 1-4, B M R No 3
B M R No 1 (Jurgurra Creek)
POOLE RANGE No 3
POOLE RANGE No 5
SAMPHIRE MARSH No 1
B M R Nos 4 & 4A (Wallal)
WALLAL No 1
BARROW Nos 1-4
MINDEROO No 1
YANREY No 1
B M R No 5 (Giralia)
WHALEBACK No 1
GIRALIA No 1
MARRILLA No 1
WARROORA No 1
WANDAGEE No 3
WANDAGEE No 1
QUAIL No 1
WANDAGEE No 2
B M R Nos 6 & 7 (Muderong)
GRIERSON Nos 1, 2 & 3
CAPE CUVIER No 1
B M R No 9 (Daurie Creek)
B M R No 8 (Mt Madeline)
DIRK HARTOG No 17 B
ABBARWARDOO No 1
MUNGARRA No 1
WICHERINA No 1
Mt HILL No 1
YARDARINO Nos 1-4
ENEABBA No 1
B M R Nos 10 & 10A (Beagle Ridge)
EGANU No 1
WOOLMULLA No 1
JURIEN No 1
HILL RIVER No 3
HILL RIVER No 2
HILL RIVER No 1
HILL RIVER No 4
GINGIN No 1
WARREN RIVER Nos 1, 2 & 3
GAMBANGA No 1
EYRE No 1
EUCLA No 1

5715

GRAVITY

Gravity surveys were conducted during 1964 in the Canning and Officer Basins. They were distributed as follows:

Company	Permit	Basin	Party Months
West Australian Petroleum Pty. Ltd.	30H	Canning	3·2
Hunt Oil Co.	147H, 148H, 134–136H, 159H	Officer	34·0
Geosurveys of Australia Pty. Ltd.	151H	Canning	2·0 (helicopter)

GEOLOGICAL OPERATIONS

Geological field investigations played a relatively small part in the exploration programmes of companies searching for oil in Western Australia during 1964, though the amount was greater than in 1963. Field investigations were carried out in the Canning, Carnarvon, Perth and Officer Basins. They were distributed as follows:

Company	Permit	Basin	Geologist Months
Continental Oil Co. of Australia Ltd.	227H	Canning	17
Do. do. do.	226H	Carnarvon	2
West Australian Petroleum Pty. Ltd.	28H	Carnarvon	4
Do. do. do.	30H	Canning	2
French Petroleum Company (Aust.) Pty. Ltd.	228H	Perth	4
Alliance Petroleum (Aust.) N.L.	205H–207H	Canning-Officer	9
Hunt Oil Co.	134–136H, 147–148H, 157–159H	Officer	4
Geosurveys of Australia Pty. Ltd.	151–152H	Canning	2½

The Geological Survey continued its mapping programme in the southern half of the Perth Basin, and this occupied two geologists for three months. In addition a geological reconnaissance of the northern Officer Basin-southern Canning Basin occupied one geologist for one month. One geologist also spent three weeks in mapping on the Lennard Shelf (northern Canning Basin).

Other geological work connected with the search for oil in this State during 1964 was mainly concerned with the review of information obtained previously and its application to the results of exploratory wells and geophysical investigations. Several companies also carried out photogeological studies.

DRILLING FOR COAL IN THE MUJA FORMATION, COLLIE MINERAL FIELD

by G. H. Low

ABSTRACT

In 1964 the Geological Survey supervised a drilling programme in the Muja Depression, 14 miles southeast of Collie, to obtain more information about the structure and coal reserves in a potential open-cut area. Seventeen boreholes were drilled in the programme, which was financed by the State Electricity Commission.

The Muja Formation, the youngest of the three formations in the depression, contains some 90 million tons of coal in 8 seams. The seams from top to bottom (with the average thickness of each shown in brackets) are: Ate (4 ft.), Bellona (8 ft.), Ceres (8 ft.), Diana (4 ft.), Eos (9 ft.), Flora (7 ft.), Galatea (9 ft.), and Hebe (38 ft.) Seams. The coal reserves consist of 14 million tons in the Western Collieries lease, and 76 million tons in the Griffin Co. leases.

Analyses of numerous samples show that all the coal seams are of commercial grade, the best being the Hebe Seam.

The Muja Formation is not as strongly faulted as was expected. The only important fault encountered during the drilling was already known to occur along the eastern side of the Hebe Colliery. Steep dips along the margins of the area are now thought to be due to differential compaction. The coal seams dip as high as 45° in at least one place on the southwestern side of the area, but the average dip of the seams throughout most of the area is only 10° to 15°.

More drilling may be necessary to check the structure and the thickness of the seams in some areas.

INTRODUCTION

A drilling programme was carried out between March and October, 1964 to elucidate the structure and coal reserves of the potential open-cut area centred about 2 miles southwest of the Muja railway siding near Collie. The State Electricity Commission financed the project which was directed by the Geological Survey.

Most of the area is in leases held by the Griffin Coal Mining Company which is already working an open-cut and a colliery at the southern end of the area. Initially a programme of 10 boreholes was decided upon by the Company and the Geological Survey but subsequently seven more boreholes were added to the original programme; six of these were selected by the Geological Survey, and the seventh by the Company to check conditions ahead of the Hebe Colliery. One of the additional boreholes was located on a lease at the northern end of the area held by Western Collieries Ltd.

The 17 boreholes (S1-S17) involved 7,804 feet of drilling. This does not include footage in some sections which were redrilled because an original borehole had to be abandoned due to drilling difficulties. Detailed logs for all the boreholes are held on File 169/64 at the Geological Survey, and summarized logs are given in Low (1964).

Previous geological work in the Muja area has been carried out by J. H. Lord, officers of the Griffin Co. and myself. Lord (1953) first described the geology of the area and named the seams. In 1958, after completion of the Mines Department exploratory drilling programme, I estimated the quantity of coal available in the potential open-cut areas as being 86 million tons (Low, 1958). It was believed at this time that the area was bounded on at least two sides by strong faulting. However subsequent company drilling showed that this structural interpretation was not entirely correct, and it was desirable to check on the structure in more detail.

The drilling was carried out by Geophysical Service International, contractors to the State Electricity Commission, using a Mayhew 1000 truck-mounted drilling rig. A 10-foot core barrel was used, fitted with a hard formation bit and a stationary inner-tube.

Electric logging was carried out in the last borehole drilled (S17) to determine if such logging methods could be used to determine the true thickness and depth of the coal seams. The results from the point-resistivity and self-potential logs were very encouraging, but unfortunately the borehole was too narrow for the gamma-ray probe (Rowston, 1964).

During the drilling valuable assistance was received from various officers of the State Electricity Commission, especially Mr. G. Rich, site engineer at Muja, and Mr. D. Saunders, chief chemist at the East Perth power station, and this is gratefully acknowledged. I am also indebted to Messrs. R. Fowler and B. Stronach of the Griffin Co., and Mr. W. Hille of Western Collieries Ltd. for many interesting discussions concerning the drilling.

GEOLOGY

The Muja Depression is a deep trough filled with Permian sediments more than 2,000 feet thick. The trough is believed to have been scoured out by ice action during the Lower Permian glaciation. Strong post-depositional compaction occurred in the Permian sediments, resulting in the basin structure, and in the development of some normal faults.

The coal seams occur in the Muja Formation, the youngest of the three coal-bearing formations in the Muja Depression. It is correlated with the Cardiff Formation of the main Collie Basin and is of Upper Permian age. The coal seams are on the western side of the Muja Depression, adjacent to a ridge of granite which, in a structural sense, divides the coal field into two unequal parts. The broad structure of the Muja Formation is an elliptical basin, the long axis of which trends northwest.

The coal seams are not exposed at the surface, but are covered by a unit of sand, clay, and conglomerate called the "Lake Beds" (Lord, 1952). The thickness of the unit in this area ranges from about 20 feet at the southern end, to about 120 feet at the northern end. In some places the top 6 feet or so are strongly lateritised forming a tough capping which may itself be covered by a thin layer of sand.

Sandstone and minor developments of shale, claystone, and siltstone are interbedded with the coal seams. Much of these sediments are weakly lithified and give poor core recovery. The core recovered, excepting the coal removed for analysis, has been stored in the Geological Survey's core shed in Wittenoom Street, Collie.

The top of the coal measures is an uneven surface due mainly to erosion before the deposition of the "Lake Beds". Although in most places the seams do not rise higher than an elevation of 700 feet, there are instances, e.g., in boreholes S3 and P257, where they rise to about 730 feet above sea level. The part of a coal seam in contact with the base of the overlying "Lake Beds" is called its "blind outcrop". The positions of the blind outcrops, estimated from borehole data, are shown on Plate 14.

Post-depositional compaction of the coal and other sediments of the Muja Formation and of the underlying formations has affected the structure of the area. Most compaction took place in the deepest part of the depression so that the dip of the beds (including the coal seams) becomes quite steep towards the edges of the formation, especially on the side adjacent to the granite ridge. This steep turning-up of the coal seams towards the blind outcrops had previously been interpreted as being due to faulting. Dips are variable, even in one borehole, but the average in the central part of the area is between 10 degrees and 15 degrees, whereas the steepest dips are found along the southwestern margin. In borehole S13 in lease 537 the Diana, Eos, and Flora Seams dip at about 45 degrees, and in borehole S15 in lease 425 the Hebe Seam dips at 37 degrees. The angle of dip of the seams between boreholes P257 and P268 at the northeastern end of section 1 is 30 degrees, and this steeply dipping structure is expected to continue around most of the blind outcrop of the Hebe Seam in lease 425. The general effect of the steepening of dip towards blind outcrops is illustrated in the geological sections on Plate 15.

The thickest penetration of the Muja Formation was made in Failing borehole 9 where the base of the deepest important seam was at 701 feet. The top of the highest seam was at 232 feet, so that the section containing the significant seams in this borehole is 469 feet thick. The thickness of the sediment interbedded between adjacent coal seams is variable and it is not practicable with the available data to draw up an accurate isopach map. However contours on the base of the Hebe Seam have been drawn (Plate 14).

There are eight major coal seams, and an average thickness for each has been calculated using the borelogs of most of the boreholes which have made complete intersections. In order of occurrence from top to bottom, with the average thickness of each in brackets, the coal seams are: Ate (4 ft.), Bellona (8 ft.), Ceres (8 ft.), Diana (4 ft.), Eos (9 ft.), Flora (7 ft.), Galatea (9 ft.), and Hebe (38 ft.) Seams. The variation in the thickness of these seams in 40 boreholes is shown in Table 1.

Table 1

THICKNESS OF COAL SEAMS

Bore	Coal Seam Thickness (in feet)							
	Ate	Bellona	Ceres	Diana	Eos	Flora	Galatea	Hebe
F6	....	....	....	....	....	....	....	35
F7	....	....	....	....	....	5	9	32
78	8	13	9	....	....	....	....	....
G83	....	....	....	....	....	....	....	40
S12	4	8	9	2	11	9	15	45
S2	3	9	10	3	11	8	12	43
188	2	11	9	4	10	6	11	40
S1/1A	....	....	....	4	11	6	12	33
P248	....	....	....	....	....	....	9	42
P252	....	....	....	....	....	....	....	40
P258	....	....	....	....	....	....	13	40
P260	....	....	....	....	....	6	12	41
S4	6	10	6	2	8	11	7	40
F9	2	5	7	5	12	5	11	44
P272	3	6	9	....	....	....	....	....
74	6	11	9	4	10	....	....	....
P273	....	....	....	4	10	9	10	41
S3	....	....	....	....	9	6	8	35
P270	2	6	10	....	....	....	....	....
P271	....	....	....	4	4	7	....	....
S16	4	11	11	3	3	7	9	35
P273	....	....	....	4	10	9	10	41
S17	6	7	7	4	8	8	8	38
S13	....	....	9	5	12	6	6	39
S7	2	8	6	3	8	....	11	38
S11	3	6	7	....	....	....	....	....
S6	5	6	7	3	....	....	5	28
S14	....	5	6	4	8	7	7	....
P234	....	....	....	....	....	7	5	31
P242	....	....	....	5	8	6	6	....
S8	....	....	....	4	10	7	8	37
79	3	9	7	3	10	6	10	39
"D"	....	....	....	4	6	6	10	37
P257	....	....	....	4	9	8	....	26
S10	3	9	10	4	11	8	12	41
Wc70	3	10	7	3	....	....	....	....
F16	....	....	....	2	9	7	8	40
S15	....	....	....	....	....	....	....	40
N3	....	....	....	....	15	6	11	40
N4	....	....	....	....	....	16	7	40
Average Thickness	4	8	8	4	9	7	9	38

In some places the coal seams are considerably below average thickness (for example in boreholes S6 and S14) and the lateral extent of this thinning is not known. Borehole S6 is particularly important because the Hebe and Galatea Seams are reduced to 28 and 5 feet respectively, and the Flora and Eos Seams are absent altogether. This borehole does not appear to have intersected any faults which could explain these anomalies. Some of the seams show substantial thinning near their blind outcrops. This applies especially to the Hebe Seam which is considerably reduced in P236 and S9 at the southwestern end of section 1 (Plate 15), and in P268 at the northwestern end of the same section. The sediments of the Muja Formation are sufficiently incompetent in most places to have reacted to compaction by folding and bedding-plane slip rather than by faulting. An exception however is the fault which has been touched at a number of places along the eastern side of the Hebe Colliery, and which has been traced by boreholes as far north as S14.

The fault is downthrown to the southwest, and appears to have an average dip of 75°. On section 4 (Plate 15) it has a throw of about 170 feet, but it appears to die out some 15 chains north of S14. If this is so then probably the lower five seams of the formation will be found to continue uninterrupted around the eastern side of the fault up to the eastern end of section 1 (Plate 15). This could provide quite a good area of relatively shallow coal.

Borehole S14 appears to have entered the fault zone somewhere below the Galatea Seam and above the Hebe Seam, because only 11 feet of coal was intersected at the depth at which the Hebe Seam was expected. Judging by the angle of the shale-coal contact at the top of the seam, the dip is nearly vertical. This section of coal probably represents part of the Hebe Seam.

There are few boreholes in Western Collieries Lease (M.L. 425) at the northern end of the area. However borehole S15 in lease 425 reached the bottom of the Hebe Seam at a depth of 205 feet and, although bedding dips as high as 37° were found in the core, there was no sign of faulting other than some bedding-plane slip. It appears therefore that structural conditions in this area are similar to those existing further south, and on this assumption the seam limits have been drawn as shown on Plate 14.

COAL RESERVES

For the purpose of estimating reserves, an average thickness has been calculated for each of the eight major seams from thicknesses measured in boreholes throughout the area. The average thicknesses are shown in Table 1. The Ate and Diana Seams, which were not included in the 1958 estimates, have now been included because the drilling has shown them to be more consistent in thickness and quality than was previously realized. They account for 5 million tons of the total reserves.

For convenience the whole area has been divided into four blocks as shown on Plate 14. The outlines of the present open-cut area and the Hebe Colliery are not shown, but allowance has been made for the coal produced from them in calculating the remaining reserves.

It should be noted that indicated and inferred categories are used because of inexact knowledge of the structure and grade of the coal in some areas. The assumptions made in the estimation of quantity are considered conservative, and no doubt is felt that the 90 million tons of coal is present within the 20% range of accuracy allowable under measured reserves.

A factor of 27 cubic feet to the ton has been used in making the calculations. Details of the estimates are given in Table 2.

Table 2

COAL RESERVES ESTIMATES

(The four areas are shown on Plate 14.)

Seam	Area (acres)	Average Thickness (feet)	Tons
AREA "A": INFERRED COAL—14 million tons			
Hebe	129	38	8,000,000
Galatea	99	9	1,400,000
Flora	92	7	1,000,000
Eos	88	9	1,300,000
Diana	83	4	500,000
Ceres	58	8	700,000
Bellona	45	8	800,000
Ate	38	4	200,000
AREA "B": INDICATED COAL—20 million tons			
Hebe	173	38	11,000,000
Galatea	154	9	2,200,000
Flora	145	7	1,600,000
Eos	138	9	2,000,000
Diana	130	4	800,000
Ceres	98	8	1,300,000
Bellona	80	8	1,000,000
Ate	61	4	400,000
AREA "C": INDICATED COAL—26 million tons			
Hebe	217	38	13,000,000
Galatea	199	9	2,900,000
Flora	189	7	2,100,000
Eos	179	9	2,600,000
Diana	165	4	1,100,000
Ceres	141	8	1,800,000
Bellona	128	8	1,700,000
Ate	108	4	700,000
AREA "D": INDICATED COAL—30 million tons			
Hebe	305	38	17,000,000
Galatea	247	9	3,600,000
Flora	215	7	2,400,000
Eos	180	9	2,600,000
Diana	173	4	1,100,000
Ceres	107	8	1,400,000
Bellona	93	8	1,200,000
Ate	78	4	500,000

TOTAL: INFERRED COAL: 14 million tons
INDICATED COAL: 76 million tons

COAL ANALYSES

Samples were taken from all the major coal seams intersected during the drilling programme. These were sealed in airtight plastic bags and placed inside cans as soon as possible after being withdrawn from the borehole, usually within 10 minutes.

All the coal recovered from the main seams was analysed, and where there was sufficient core recovery the analyses represent 3 or 4 foot sections. However where core recovery was poor the coal recovered has been taken to represent thicker sections. Separate samples were analysed for poor quality coal or shaly bands in a seam.

The samples were analysed by the proximate method at the State Electricity Commission power station in East Perth. The results are consistent with earlier analyses of the coal seams in this formation. The best quality coal is in the Hebe Seam, but all the seams are of commercial quality. A table of coal sample analyses is given by Low (1964).

OPEN-CUT MINING

The difficulties involved in the open-cut extraction of coal from the Muja Formation are increased by the fact that several seams are to be worked. The thick seam at the bottom (Hebe Seam) can be extracted with economic coal-overburden ratios for a considerable distance along the strike, especially around the southern and southeastern limits of the formation; but as the cut is developed down-dip, the extraction of the overlying seven seams will be necessary in order to maintain economic ratios. The extraction of coal from the Hebe Seam by deep mining in the Hebe Colliery will cause problems when the open-cut is extended to this area.

An estimate has been made of the coal/overburden ratios for each borehole that intersected significant thicknesses of coal. This has been done for 43 boreholes as shown in Table 3. To arrive at ratios including all the seams it has been necessary to assume the thickness and depth of some of the lower seams in 11 boreholes which were not carried down to intersect the base of the Muja Formation. An allowance was made for the dip of the seams so that the true thicknesses are used in the calculations. These ratios are shown on Plate 14.

Table 3

COAL/OVERBURDEN RATIOS

Bore	Seam(s)	Dip	Thickness (A = assumed)	Thickness Corrected	Base of Hebe Seam	Ratio Coal/Overburden
			feet		feet	
F6	Hebe	7°	35	35	80	1/1·3
F7	Flora-Hebe	32°	46	41	238	1/4·7
78	Ate-Hebe	6°	A 101	101	465	1/3·6
G83	Hebe	10°	40	39	65	1/0·6
S12	Ate-Hebe	10°/20°/30°	103	96	513	1/4·3
S2	Ate-Hebe	7°	99	97	665	1/5·8
188	Ate-Hebe	7°	A 92	90	590	1/5·6
S1/S1A	Diana-Hebe	5°	66	66	280	1/3·2
P248	Galatea-Hebe....	17°	51	48	158	1/2·3
P252	Hebe	17°	40	38	101	1/1·6
P258	Galatea-Hebe....	17°	53	50	182	1/2·6
P260	Flora-Hebe	17°	59	56	231	1/3·1
S4	Ate-Hebe	10°	90	88	662	1/6·5
F9	Ate-Hebe	5°	91	91	701	1/6·7
P272	Ate-Hebe	7°	A 89	87	670	1/6·5
74	Ate-Hebe	10°	A 97	94	620	1/5·6
P273	Diana-Hebe	5°	74	74	359	1/3·9
S3	Eos-Hebe	25°	58	50	213	1/3·3
P270	Ate-Hebe	7°	A 89	87	670	1/6·7
P271	Diana-Hebe	5°	A 62	62	356	1/4·8
S16	Ate-Hebe	10°	80	78	538	1/5·6
P273	Ate-Hebe	5°	74	74	359	1/3·9
S17	Ate-Hebe	5°	86	86	705	1/7·2
S13	Ceres-Hebe	20°	77	73	484	1/5·6
S7	Ate-Hebe	20°	76	72	561	1/6·8
S11	Ate-Hebe	10°	A 85	83	550	1/5·6
S6	Ate-Hebe	10°	54	52	501	1/8·6
S14	Bellona-Hebe....	10°/40°	A 67	50	410	1/7·2
P236	Hebe	30°	7	7	118	1/16
S9	Hebe	30°	13	10	193	1/16·6
P234	Flora-Hebe	20°	43	41	277	1/5·8
P242	Diana-Hebe	20°	59	56	350	1/5·2
S8	Diana-Hebe	10°	66	64	477	1/6·5
79	Ate-Hebe	5°	87	87	502	1/4·8
D	Diana-Hebe	10°	63	60	454	1/6·6
P257	Diana-Hebe	20°	47	44	368	1/7·3
P268	Diana-Hebe	30°	46	40	274	1/5·8
S10	Ate-Hebe	5°	98	98	629	1/5·4
Wc70	Ate-Hebe	20°	A 86	81	550	1/5·8
F16	Diana-Hebe	20°	66	63	480	1/6·6
S15	Hebe	30°	40	35	204	1/4·8
N3	Eos-Hebe	10°	A 72	70	380	1/4·4
N4	Flora-Hebe	30°	A 63	55	360	1/5·5

The coal/overburden ratios for the boreholes in the Griffin Co. leases in Table 3 suggest that 76 million tons of coal is available at an average ratio of 1 to 5.6. Better-than-average ratios are present near the southern and southeastern margins of the formation due mainly to the gentler dips and thinner "Lake Beds" in these places.

The discovery that the lateral limits of the formation are unfaulted eases the open-cut problems considerably. Nevertheless the steep dip of the Hebe Seam near its blind outcrop on the southwestern, northern, and northeastern sides will make coal extraction difficult in those places.

As far as can be judged from the drill core none of the material in the coal measures will be any more difficult to remove by ripping than that already extracted from the open-cut. The toughest rock encountered during drilling occurred in bands a few inches thick cemented by either marcasite (iron sulphide) or silica. However these thin bands are discontinuous and should present no problems in extraction. Some moderately hard sandstone was found in the fault shear-zone in borehole S14, and more of this can be expected elsewhere along the fault; but this rock is strongly jointed and this should facilitate extraction.

The laterite at the top of the "Lake Beds" is tough and massive in places, and this may pose some problems especially towards the northern end of the area.

Difficulty was experienced in maintaining mud circulation in some uncased boreholes at the level of the Diana and Galatea Seams, and near the top of the Hebe Seam. In these places the sandstone (actually sand) was sufficiently coarse-grained, loose and permeable to allow the drilling fluid to escape. No artesian or sub-artesian water pressures were recorded during drilling but it is realized that the weight of the drilling mud could have kept back water under moderate pressure if any was in fact encountered. However percussion holes throughout the area (although not generally as deep as the rotary holes) have not intersected any significant pressure-water aquifers and it is not expected that pressure-water will pose any major problems during open-cut operations.

RECOMMENDATIONS

Although the drilling done since the last report of the Geological Survey (Low, 1958) is sufficient to show that the Muja Formation is not as severely affected by faulting as was previously expected, there are still many places where details of the structure are uncertain. The drilling validates the estimates made in 1958, but the estimates cannot yet be raised above the "indicated" and "inferred" categories because of inexact knowledge of the structure and grade of the coal in some areas. More drilling may be necessary for efficient planning of the open-cut and if so it should be directed toward clarification of the following points:

1. Location of the blind outcrops and the dip of the coal seams, especially the Hebe Seam, on the southwestern, northern, and northeastern sides of the area.

2. Extent of thinning of the coal seams around borehole S6.

3. Northward extent of the major fault on the eastern side of the area.

4. Coal/overburden ratios in sufficient detail throughout the area to permit compilation of accurate isopach maps.

It is also recommended that a detailed surface contour map of the entire area should be prepared before any further detailed investigations are carried out.

In any future coal drilling programme further experimental electric logging should be carried out on one of the first holes drilled. The minimum diameter of the hole would need to be 5½ inches so that the gamma-ray log could be run as well as the resistivity and self-potential logs. If the experiment is successful rotary holes could be drilled without coring unless coal samples are required. This would result in considerable savings in time and expense.

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DRILLING OF UPPER CRETACEOUS GLAUCONITE DEPOSITS AT DANDARAGAN, GINGIN AND BULLSBROOK

by G. H. Low

ABSTRACT

Upper Cretaceous greensands north of Perth were drilled by 13 auger holes to assess quantity, potash content and attitude of the beds.

At Dandaragan, glauconite reserves are estimated at 3.5 million tons containing 5.4% K_2O overlain by 6 million tons containing 2.3% K_2O. Data in other areas is insufficient to estimate reserves.

At Dandaragan and Gingin the greensands dip at about 1° to the east and southeast, and at Bullsbrook they dip to the west at about 1¾°.

INTRODUCTION

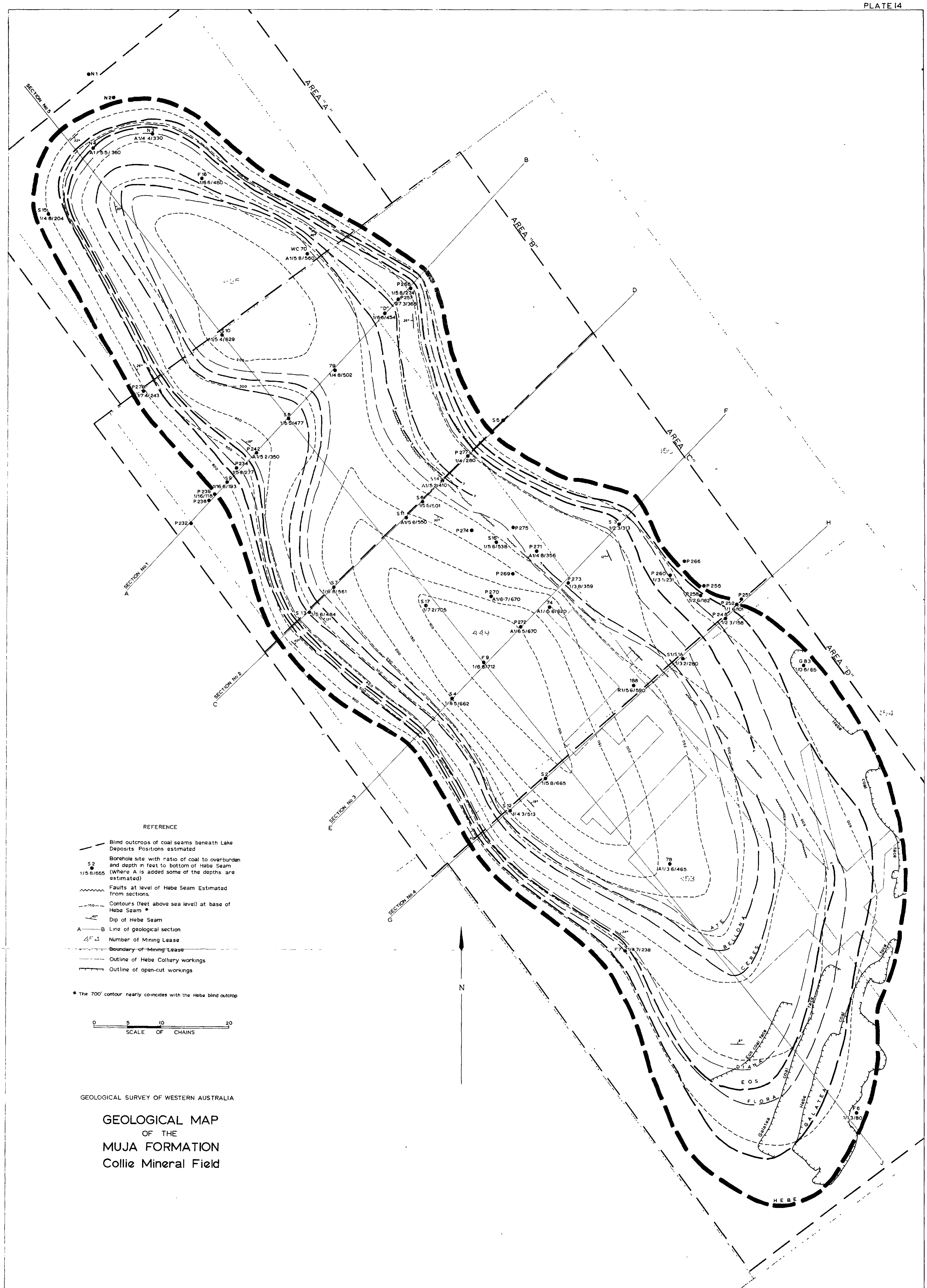
A programme of 13 auger holes was drilled by the Geological Survey to obtain glauconite samples and stratigraphic information from Upper Cretaceous greensands in the Dandaragan, Gingin and Bullsbrook areas. This was done at the request of W. E. Ewers, officer in charge of the C.S.I.R.O. Secondary Industries Laboratory in Perth, to assist the appraisal of the greensands as a source of potash for agricultural and industrial use.

The best-known and most accessible occurrences of greensand in the Perth Basin occur around Dandaragan and Gingin, small farming district towns 85 and 43 miles respectively north of Perth. The glauconite in these two areas occurs in two formations: the Poison Hill Greensand (upper greensand) and the Molecap Greensand (lower greensand).

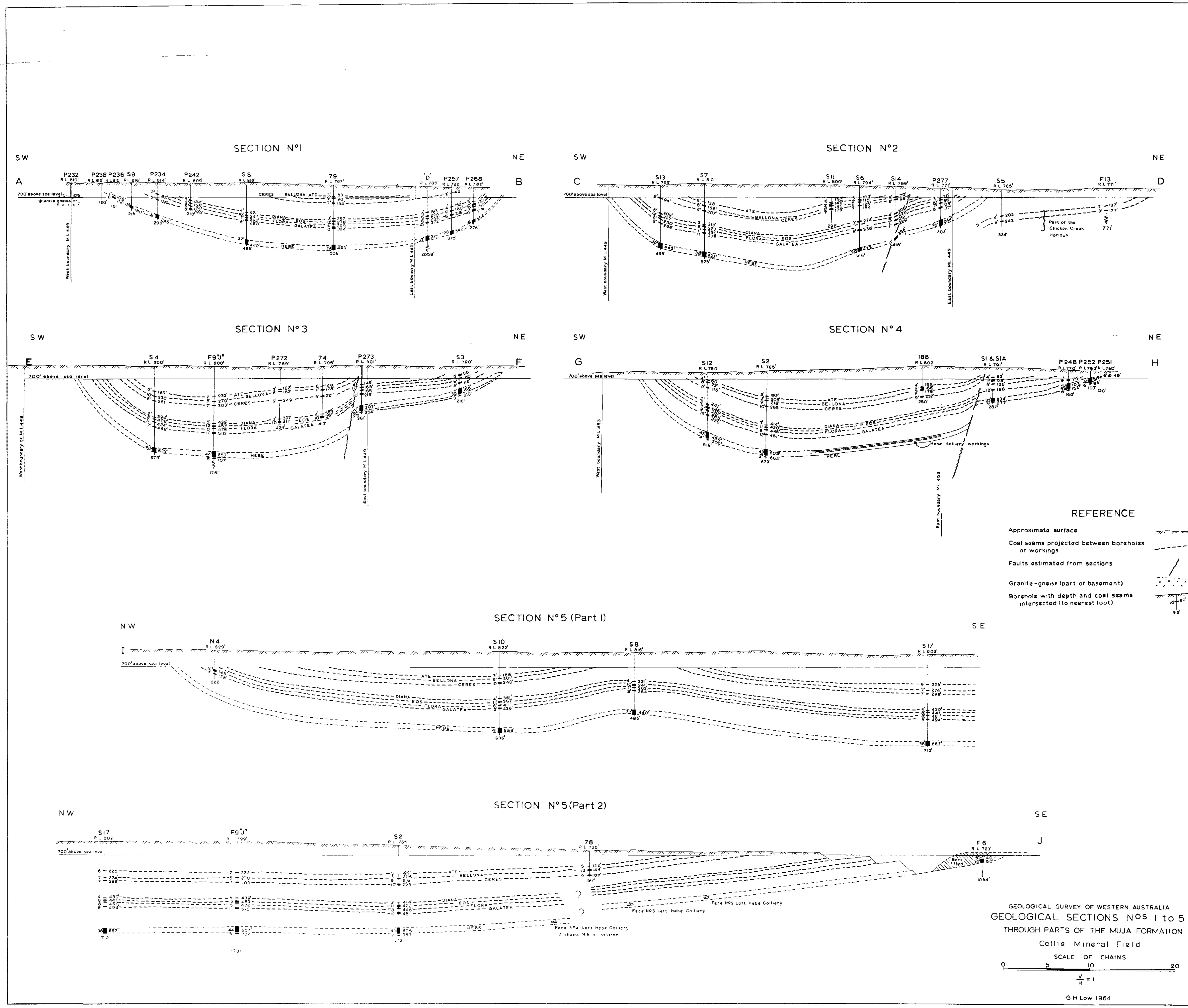
Three holes were drilled through the Poison Hill Greensand and three through the Molecap Greensand in both the Gingin and Dandaragan areas. The holes were widely spaced to obtain information on any facies variation in the greensands. The final hole was drilled at Bullsbrook where a greensand occurrence was known (Metropolitan Survey File 1951/52), from two water wells 23 miles northeast of Perth on the slopes of the Darling Range. The logs for the 13 holes are summarised in Low (1965), and the locations are shown on Plate 16.

The holes were drilled using a Mines Department Gemco rig fitted with an auger bit. Drilling commenced at Dandaragan on 5th December 1963 and was completed at Bullsbrook on 6th April, 1964.

PLATE 14



8521


SECTION Nº1
SW
NE
A
B
SECTION Nº2
C
D
SECTION Nº3
E
F
SECTION Nº4
G
H
SECTION Nº5 (Part 1)
NW
SE
I
SECTION Nº5 (Part 2)
J
700' above sea level
CERES
BELLONA
ATE
DIANA
EOS
FLORA
GALATEA
HEBE
Hebe colliery workings
Face Nº4 Left Hebe Colliery
Face Nº3 Left Hebe Colliery
Face Nº2 Left Hebe Colliery
Part of the Chicken Creek Horizon
REFERENCE
Approximate surface
Coal seams projected between boreholes or workings
Faults estimated from sections
Granite-gneiss (part of basement)
Borehole with depth and coal seams intersected (to nearest foot)
GEOLOGICAL SURVEY OF WESTERN AUSTRALIA
GEOLOGICAL SECTIONS Nos 1 to 5
THROUGH PARTS OF THE MUJA FORMATION
Collie Mineral Field
SCALE OF CHAINS
0
5
10
20
V/H = 1
G H Low 1964

8522

A preliminary laboratory report by C. E. S. Davis of the C.S.I.R.O. on the composition of greensand samples provided the chemical data used in this report.

GEOLOGY

Scattered exposures of the Upper Cretaceous Poison Hill and Molecap Greensands occur in a zone of variable width which trends north-northwest from about 7 miles south-southeast of Gingin to about 20 miles past Dandaragan. South of Moore River this zone forms an eroded escarpment along the western edge of an elevated sand and laterite-covered plain which extends eastward to the Darling Fault. East of the fault is the granite-gneiss complex of the Western Australian Precambrian Shield. North of the Moore River the escarpment is less distinct, giving way to rounded slopes and some isolated hills with abrupt breakaway faces. The zone of greensand exposures attains a maximum width of about 12 miles at Dandaragan.

The Poison Hill and Molecap Greensands, which are separated by the Gingin Chalk, appear in outcrop as ferruginised red-brown clayey sandstones. They are glauconitic in some areas but there are no unweathered natural exposures.

The greensands presumably extend eastwards to the Darling Fault beneath the superficial cover, but this has not been checked by sub-surface exploration. To the west, between the escarpment and the coast, the underlying Lower Cretaceous and Jurassic rocks are obscured by Pleistocene and Recent sand and limestone.

The two water wells which encountered greensand of the Osborne Formation at Bullsbrook are near the 350-foot contour level on the lower slopes of the Darling Range. They were sunk through a surface cover of gravelly loam about ½ mile west of an outcrop of laterite developed over gneiss, which is the closest exposure of the Precambrian rocks. No outcrops of the Osborne Formation have been seen, and the areal extent of the formation in this area is not known.

STRATIGRAPHY

Table 1 shows the thickness of the various formations and other units in each hole. In the table and the following text, Dandaragan glauconite holes are abbreviated to DGH, Gingin glauconite holes to GGH, and Bullsbrook glauconite holes to BGH.

Table 1

THICKNESS OF FORMATIONS IN AUGER HOLES (in feet)

Hole	Sand	Poison Hill Greensand	Gingin Chalk	Molecap Greensand	Dandaragan Sandstone	South Perth Formation	Approximate Depth of Weathering
			DANDARAGAN				
DGH 1	....	135	6	....	....	....	95
DGH 2	....	120	5	....	....	....	70
DGH 3	....	....	10	20	82	....	30
DGH 4	....	....	....	54	1	....	55
DGH 5	....	....	....	46	2	....	48
DGH 6	30	120	....	....	....	....	110
			GINGIN				
GGH 1	....	....	....	44	6	....	35
GGH 2	....	135	....	....	....	....	95
GGH 3	....	....	45	5	3	22	....
GGH 4	....	....	5	91	1	3	55
GGH 5	....	....	15	35	10	....	....
GGH 6	20	73	....	....	....	....	93
			BULLSBROOK				
				Osborne Formation			
BGH 1	....	....	....	138	....	17	12

Sand and Laterite

Alluvial sand occurs on the elevated plain, east of the escarpment, in broad shallow drainage channels and in pockets on the slopes of the escarpment. However most of the sand occurring on the plain and covering the Upper Cretaceous formations is residual, forming part of the normal lateritic profile.

Thicknesses of 30 and 20 feet of sand were penetrated in DGH 6 and GGH 6 respectively. Most of this sand is loose or only very weakly lithified but it contains an increasing proportion of clay and hard nodular ferruginous sandstone towards the base.

Laterite is widely developed over the greensands in the Dandaragan and Gingin areas, and some of the drilling commenced in either pisolitic or massive laterite. The maximum surface concentration of iron is in DGH 5 where Fe_2O_3 was found to average 48.9% in the top 15 feet. Other results were 30.3% down to 5 feet in DGH 1, 36.8% down to 10 feet in DGH 4, and 45.0% down to 5 feet in GGH 1.

A lateritic hardpan was found near the water table in some holes. In DGH 1 samples between 75 and 90 feet average 21% Fe_2O_3, and in DGH 2 a sample from 40 to 45 feet gave 24.3% Fe_2O_3.

The full thickness of the sand, laterite and strongly ferruginised layers is not known but it may be as much as 50 feet in the plain country to the east.

Poison Hill Greensand

The Poison Hill Greensand consists of weakly lithified clayey glauconitic sandstone and carbonaceous glauconitic claystone, with some thin shaley bands. In DGH 1, DGH 2, DGH 6, and GGH 2, there are 30, 39, 40, and at least 55 feet respectively of dark grey-green to black glauconitic clay immediately above the Gingin Chalk. This is unweathered greensand and it is considerably richer in potash than the overlying material.

The maximum thickness of the Poison Hill Greensand was encountered in GGH 2 at Poison Hill, where the type section for the formation is located. The hole penetrated 135 feet of Poison Hill Greensand before it was abandoned due to drilling difficulties. From 130 to 135 feet the CaO content was 3.1%, which may be due to interfingering with the Gingin Chalk but is more likely to be due to the presence of calcareous fossils in the greensand.

Weathering in the Poison Hill Greensand extends to a maximum depth of 95 feet (DGH 1 and GGH 2) and this has resulted in a leaching of potash and enrichment in iron. In places the weathered greensand is a brown ferruginous sandstone.

The Poison Hill Greensand has been dated by H. S. Edgell (pers. comm.) as Campanian to Upper (?) Santonian in age from the study of samples collected during the drilling. It rests conformably on the Gingin Chalk, and in some places there may be some minor interfingering between the two formations.

Gingin Chalk

The Gingin Chalk is a grey to white, richly fossiliferous chalk, which is somewhat glauconitic at the top and the base. It is Santonian in age.

The maximum penetration of the formation was 45 feet in GGH 3. At this site the top of the Chalk is eroded but the hole penetrated the base of the formation. Its maximum thickness in outcrop is 70 feet in McIntyre Gully, 2 miles north of the Gingin Railway Station (Feldtmann, 1963). However it is a lenticular formation and can be expected to vary considerably in thickness between Gingin and Dandaragan; it may even be absent in some places. Some apparent interfingering with the underlying Molecap Greensand may be seen in the northern face of the Molecap Quarry, but it has been suggested by P. E. Playford (pers. comm.) that the thin chalky layers in the greensand are due to slumping or precipitation of lime from ground waters.

Molecap Greensand

The Molecap Greensand rests conformably beneath the Gingin Chalk, and it is apparently conformable on the Dandaragan Sandstone below. The formation is 91 feet thick in GGH 4, and this is the thickest section recorded to date.

In the Dandaragan area two well-developed phosphatic beds, each about 2 feet thick, lie at the top and the base of the formation. Matheson (1948) states that the phosphate is present as collophanite in nodules and replacing pieces of wood, and as the iron phosphates dufrenite and vivianite in the greensand matrix. The phosphate beds do not appear to be so well developed in the Gingin area, although Feldtmann (1963) records that at Molecap Hill a thin band with phosphate nodules is said to have been found at the base of the formation during quarrying operations, and that a band 3 to 30 inches thick of dark red-brown ferruginous material at the top of the formation carries phosphatic nodules up to 8 inches in diameter.

Phosphate was determined in a few of the samples from the drilling, and the best results were 3.1% P_2O_5 at the base of the Molecap Greensand in DGH 3 and 2.0% P_2O_5 between 10 and 15 feet at the base of the Gingin Chalk in GGH 5 at Molecap Hill. DGH 4 at the "Hole in the Wall" phosphate deposit, and DGH 5 at the "Caves" phosphate deposit, two of the occurrences described in some detail by Matheson (1948), showed only 0.3% and 1.2% P_2O_5 respectively. However too much reliance should not be placed on these results because auger sampling methods are not very satisfactory where the phosphate is mainly in nodular form.

The Molecap Greensand is deeply weathered except where overlain by the Gingin Chalk. It usually contains less glauconite than the Poison Hill Greensand and is somewhat richer in glauconite at Gingin than at Dandaragan.

The Molecap Greensand has been dated as Upper Cretaceous (Santonian) in age by H. S. Edgell (pers. comm.)

Osborne Formation

Palaeontological examinations by H. S. Edgell (pers. comm.) show that the 138 feet of glauconitic clay and sand in BGH 1 is part of the Upper Cretaceous (Cenomanian) Osborne Formation. The material penetrated is a yellow, red-brown, and green-grey clayey glauconitic sandstone, with some brown argillaceous siltstone. The top 12 feet is somewhat weathered, showing slight ferruginisation. This section averaged 2.3% K_2O, and the next 100 feet averaged 3.0% K_2O. The top 50 feet averaged 3.1% K_2O, which is a better near-surface percentage than in any other hole.

It appears that the Osborne Formation overlies 17 feet of South Perth Formation in this hole, but the nature of the contact is not known.

Dandaragan Sandstone

The thickest section of Dandaragan Sandstone penetrated during the drilling programme is in DGH 3 where it is 82 feet thick, but the base was not reached. It is a cross-bedded or massive, coarse to very coarse-grained, feldspathic sandstone, conglomeratic in places. It is apparently conformable beneath the Molecap Greensand and rests with angular unconformity on the Yarragadee Formation (Dandaragan area) or on the South Perth Formation (Gingin area). Analyses of samples from GGH 3, 4, and 5 showed more potash (probably as sericite) in the Dandaragan Sandstone than in the green sand just above.

Although no diagnostic fossils have been found in the Dandaragan Sandstone, it is probably Upper Cretaceous in age (McWhae and others, 1958).

South Perth Formation

A few feet of orange and purple, sandy siltstone was penetrated near the bases of GGH 3, GGH 4, and BGH 1. This section is correlated with the Lower Cretaceous (Aptian-Neocomian) South Perth Formation by H. S. Edgell (pers. comm.), and it is regarded as being laterally equivalent to the upper part of the Yarragadee Formation.

STRUCTURE

In the Dandaragan area the limited exposures indicate that the Upper Cretaceous rocks dip at 1° to 4° to the southeast, with occasional reversals of dip which suggest gentle warping (Matheson, 1948). The altitudes of the holes are only known approximately, but from DGH 3, 4, and 5 it is estimated that the dip of the Molecap Greensand in the area is only 0° 45′ to the east-southeast. The base of the Poison Hill Greensand drops only about 130 feet between DGH 1 and 6, a distance of almost 14 miles.

At Gingin the dips of the top and the base of the Molecap Greensand, estimated from GGH 3, 4, and 5, are to the east and the west respectively, both being less than 1 degree. The base of the Molecap Greensand is only about 200 feet lower at Gingin than at Dandaragan.

At Bullsbrook the base of the Osborne Formation was cut at about 212 feet above sea level in BGH 1, whereas in the No. 3 Pearce aerodrome bore, 2.7 miles to the west, it occurs at about 250 feet below sea level, a difference in elevation of approximately 460 feet. This difference is thought to be due to a westerly dip of about 1¾ degrees rather than to faulting. Seismic work has shown a possible reversal from the regional easterly dip in deeper formations in this area (Walker and Raitt, 1964).

RESERVES

Because of insufficient outcrops, deep weathering, and inadequate sub-surface exploration (by drilling or pits), it is not possible to make satisfactory estimates of reserves for most of the areas in which the greensands occur.

An exception is in the vicinity of DGH 2 in the Dandaragan area where the nature of the outcrop and topography permits a minimum estimate to be made. Using a density of 15 cubic feet to the ton, it is estimated that there is 6 million tons of weathered Poison Hill Greensand carrying 2.3 per cent. K_2O, overlying 3.5 million tons of fresh Poison Hill Greensand carrying 5.4 per cent K_2O. The weathered material is 70 feet thick and the fresh material is 40 feet thick.

CONCLUSIONS

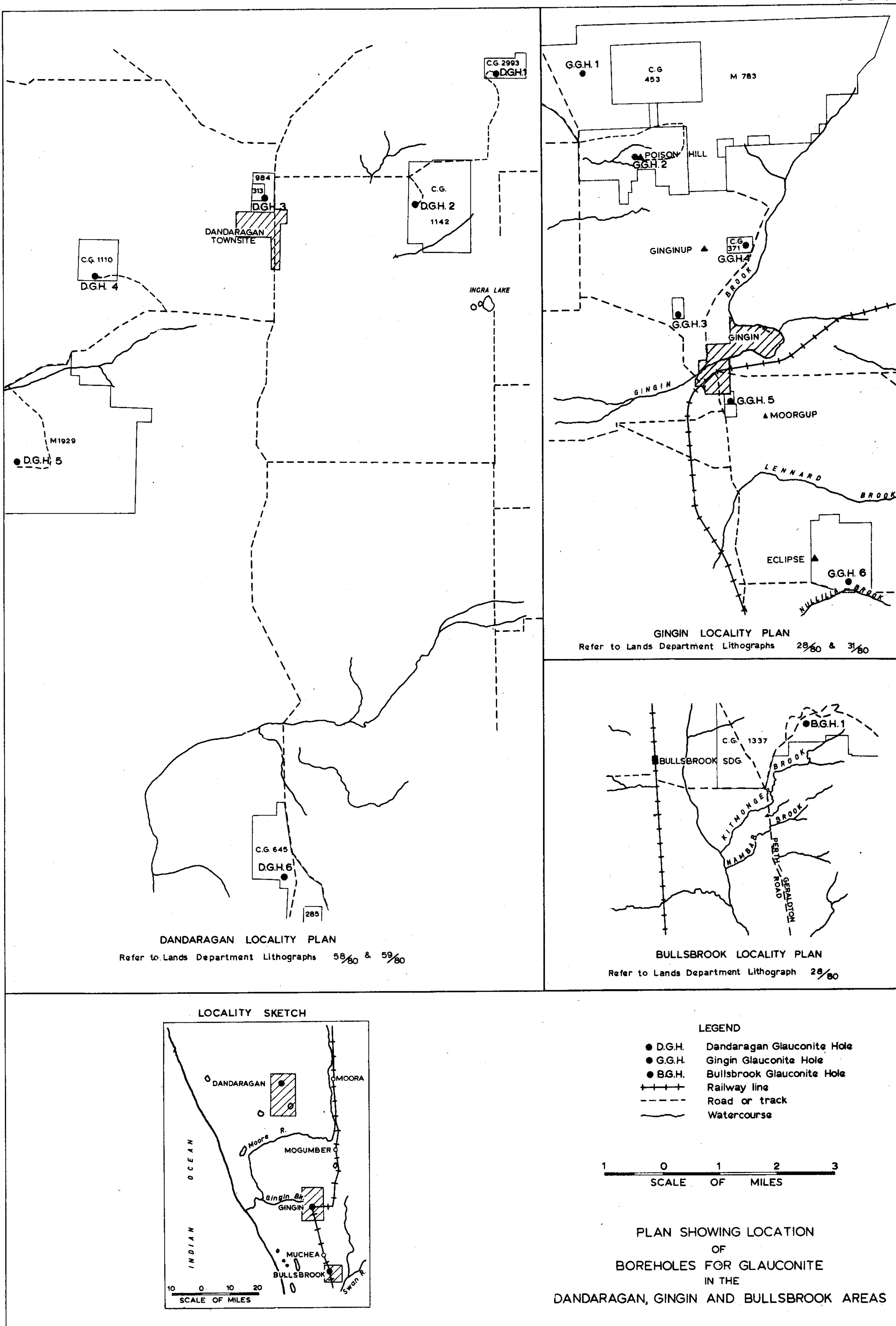
The Poison Hill Greensand was found to be strongly weathered down to a maximum depth of 110 feet. Below the weathered greensand in DGH 2, DGH 6, and GGH 2, sections of unweathered grey-green to black glauconitic clay, ranging in thickness from 30 to 55 feet, were found to contain 4½ to 5½ per cent K_2O. The highest potash percentage (average 5.4 per cent. K_2O between 70 and 110 feet) was found in DGH 2.

The Molecap Greensand was tested in DGH 3, 4, and 5, and GGH 1, 3, 4, and 5. It contains less glauconite (maximum of 3.6 per cent K_2O in GGH 1 and 5) than the best sections of the Poison Hill Greensand, but the thickness of the weathered material over the Molecap Greensand is generally thinner than is the case with the Poison Hill Greensand.

The greensand unit at Bullsbrook (the Osborne Formation) is topographically suited to a detailed investigation by drilling, and may prove suitable for quarrying. The potash percentage (2.3 per cent to 12 feet below the surface and 3.0 per cent. from 12 to 112 feet) is less than for the best sections in the Poison Hill and Molecap Greensands, but the relatively high near-surface potash content at the Bullsbrook locality and its convenient location are factors in its favour.

The planning of future investigations by drilling of the glauconite deposits depends upon the results of current potash extraction experiments being made by the C.S.I.R.O. Boreholes may be sited to prove reserves of the near-surface lower grade material in the Molecap or Osborne Formations, or reserves in the deeper but higher grade sections of the Poison Hill Greensand.

PLATE 16



PLAN SHOWING LOCATION OF BOREHOLES FOR GLAUCONITE IN THE DANDARAGAN, GINGIN AND BULLSBROOK AREAS

8605

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PROTEROZOIC GRANITES OF THE ASHBURTON REGION, NORTH-WEST DIVISION

by J. L. Daniels

ABSTRACT

Four Proterozoic granites from the Ashburton Region are discussed. Their petrography, contact effects and structural setting are described and their economic possibilities outlined.

INTRODUCTION

Granitic rocks have long been known in the northwest of Western Australia. Early descriptions of granitic rocks from the region between Nanutarra and Maroonah are given by Talbot (1926), who also states (p. 61, 62) "the granite on the Gascoyne near Lockier Range, described by Mr. Maitland in Bulletin No. 33 (1909), is probably an extension of the same belt." Probably part of the same suite are the granites to the north of Nanutarra and extending intermittently to Peedamullah; those just west of Parry Range, Mt. Alexander and Uaroo; and those near Lyndon. The approximate distribution of these masses is given on the Tectonic Map of Australia (published 1960).

An airborne magnetic and radiometric survey of the Carnarvon Basin was made by the Bureau of Mineral Resources between 1956 and 1961 (Spence, 1962). This survey extended a short distance into the Precambrian and located several radiometric anomalies, some of which were associated with granitic rocks.

Recent mapping of the Wyloo 1 : 250,000 Sheet (SF/50-10) by the Geological Survey has delineated the boundaries of the following granitic masses (Plate 17):

Mt. Danvers Granodiorite

Wongida Creek Granodiorite

Boolaloo Granodiorite

Kilba Granite.

This report is a summary of the available knowledge concerning samples from individual granitic bodies, some of their contact regions and the asssociated rocks.

AGE

All the granitic rocks in the northern part of the area intrude metamorphosed sediments of the Wyloo Group (Halligan and Daniels, 1964). This is probably also the case further south in the Edmund and Minilya Sheet areas. In the Henry River region, the granites are unconformably overlain by the Bangemall Group.

Their relationship to the Bresnahan Group is not definitely known, but tourmaline-rich schists occur as pebbles and boulders in the Cherrybooka Conglomerate (the lower formation of the Bresnahan Group). These could be related to the abundant examples of tourmaline-impregnated schists of the Wyloo Group, seen in the Wongida Creek Granodiorite, and suggest that the emplacement of one or more of the granites may have taken place before the Bresnahan Group was deposited. In the Wyloo and Yarraloola Sheet areas there are several isolated outliers of sandstone, quartzite and conglomerate which are tentatively correlated with the Bresnahan Group. They overlie the Ashburton Formation and are unconformably overlain in one place by Bangemall Group sediments. They are not known to contain any granite pebbles and, along the western face of the Parry Range, are intruded by granite. This particular granite is not well exposed but may be a continuation of the Kilba Granite.

One age determination on the Boolaloo Granodiorite (Leggo and others, 1965) indicates an age of 1,720 million years.

Some of the granitic rocks show the effects of shearing while others are structurally homogeneous, probably indicating that intrusion took place over an interval of time during the waning phases of the Ophthalmian Fold Period (Halligan and Daniels, 1964).

STRUCTURAL SETTING

The central and southern sections of the Hamersley Range show a strong development of easterly trending fold structures (MacLeod and others, 1963; Halligan and Daniels, 1964). Followed to the west, these structures gradually swing to a northerly trend. It is in this northerly trending zone that the granitic rocks are intruded and is here also where the highest grade of regional metamorphism is attained.

Near Kooline homestead, 14 miles south of Mt. de Courcey, the Ashburton Formation shows the effects of dynamic metamorphism, with production of strong cleavages. No regional metamorphic consequences have been noted and the local fold axes show a general westerly trend. Some 36 miles to the northwest, near Mt. Danvers, mica schists are common. Minor fold axes in this area have a northwesterly trend. Between Mt. Alexander and the Parry Range minor fold axes generally show a northwesterly to northerly trend. Near Mt. Alexander very coarse mica schist and plagioclase amphibolite are abundant.

GENERAL CHARACTERISTICS

The granites generally give rise either to low sandy plains with isolated monadocks or to slightly undulating ground, strewn with granite boulders.

Fresh surfaces are white or light grey, but they weather to pale yellow-brown. Some of the granite of Black Hill, and of the small hills to the west and southwest of Mt. Hubert is anomalous in that it weathers to very dark brown, or almost black. This is caused by a thin coating, possibly of an iron mineral, associated with jointing. Between this dark outer layer and the unweathered granite is a bleached zone up to a quarter of an inch wide. The staining and the associated bleaching may have been caused by late hydrothermal activity.

The Boolaloo body frequently occurs as accumulations of boulders which show only a very thin skin of weathered material. In the Kilba Granite the depth of weathering varies widely; some areas show deep weathering producing a very friable granite crust and jagged hills whereas elsewhere in the same granite exfoliation commonly exposes fresh granite and gives rise to smooth rounded dome-shaped hills.

DESCRIPTIONS OF INDIVIDUAL INTRUSIONS

Mt. Danvers Granodiorite

Some 4 miles southeast of Mt. Danvers is a small oval outcrop of granitic rock occupying an area of approximately 14 square miles (Plate 17). It has a maximum length of 8 miles. It intrudes cleaved shale and mica schist of the Ashburton Formation and is unconformably overlain in the southwest by the Bangemall Group. Fresh dolerite dykes cut the granite and also extend into the Bangemall Group. Along the line of the unconformity, faulting accompanied by intense shearing has affected the mass, with the consequent production of a zone of granitic gneiss some 50 yards wide.

The main mass is composed of quartz, plagioclase, microcline and biotite with accessory iron oxide, zircon, sphene, apatite, epidote, chlorite and possible prehnite. It may be termed a granodiorite (Table 1, No. 3). The quartz, as a mosaic of small crystals, forms irregularly shaped "pools". It also occurs as fine-grained inclusions in plagioclase and to a lesser extent in the biotite. The plagioclase is sericitised and saussuritised andesine (An_{35}), with rare remaining fresh areas showing albite twinning or, rarely, albite-carlsbad combinations. Some crystals are zoned. Several crystals show moderately fresh, thin rims, probably preserved on account of their more albitic composition allowing less secondary alteration. The biotite, green-brown and strongly pleochroic, possesses ragged terminations and carries inclusions of opaques, quartz and zircon, the latter surrounded by very strongly pleochroic haloes. Slight replacement of the biotite by epidote, chlorite and possible prehnite was noted. Frequently the biotite and iron oxide forms aggregates with associated fine-grained quartz and relatively fresh, fine-grained andesine (An_{35}).

Table 1

MODAL ANALYSES OF THE GRANITIC ROCKS

	1	2	3	4	5
Quartz	39·7	35·9	38·2	27·0	31·2
Plagioclase	36·1	31·4	33·4	39·8	38·5
Potash Feldspar	5·9	10·7	8·8	25·4	20·3
Biotite	17·1	20·6	19·1	4·5	1·0
Muscovite	....	0·2	0·1	2·7	8·4
Tourmaline	0·6	....	....	....	0·1
Opaques	0·2	....	....	....	....
Apatite	....	0·1	0·3	0·3	0·1
Zircon	0·1	....	....	....	Trace
Epidote	0·2	1·1	....	....	....
Calcite	....	....	....	0·3	0·3
Total	99·9	100·0	99·9	100·0	99·9
Plagioclase anorthite percentage	35–40	10–15	35	10	7

1. Boolaloo Granodiorite
2. Wongida Creek Granodiorite
3. Mt. Danvers Granodiorite
4. Kilba Granite
5. Kilba Granite

Rare quartz veins cut the granodiorite. They carry traces of muscovite and abundant trails of minute liquid inclusions with gas bubbles.

The granodiorite is slightly xenolithic, the xenoliths being of the order of one or two inches in diameter, and well rounded. One example consists of a fine-grained aggregate of ragged flakes of green-brown biotite and evenly disseminated subhedral magnetite in a groundmass of plagioclase laths and a small amount of fine-grained anhedral quartz. The texture and petrography would suggest that the original rock was a medium-grained igneous rock of intermediate composition.

Wongida Creek Granodiorite

A granitic mass intrusive into metamorphosed sediments of the Ashburton Formation occupies an area of approximately 34 square miles, just west of Wongida Creek, and is unconformably overlain by the Bangemall Group. Wongida Creek flows along the line of the unconformity on the eastern margin of the mass.

The granite is locally gneissose, and many pegmatite and aplite dykes cut the body. Xenoliths are present.

In thin section the rock is composed of quartz, microcline microperthite, plagioclase and biotite with accessory opaques, chlorite, epidote, sphene, apatite and zircon (Table 1, No. 2). The microcline is usually fresh and shows cross-hatched albite-pericline twinning either alone or combined with simple carlsbad twinning. It is subordinate to the plagioclase (andesine) which has been almost completely sericitised and saussuritised and rarely shows unaltered relics. The biotite is dark brown and carries inclusions of, or is closely associated with, opaques, epidote and sphene. It is largely replaced by green chlorite showing anomalous green and brown interference colours.

Towards the western margin of the intrusion, near the Henry River, there is a muscovite-rich tourmaline granite facies.

In contrast to the highly altered host rock are the fresh aplite veins. They consist of a fine-grained mosaic of quartz, microcline, plagioclase and muscovite with traces of iron oxide, garnet, apatite and very rare epidote and chlorite. The plagioclase has a composition of An_{10-15} and occasionally shows very slight sericitisation.

Thin pegmatites are locally abundant and consist of quartz and white feldspar, often in graphic intergrowth, abundant tourmaline and some muscovite.

Some of the large schist xenoliths show abundant tourmaline, and in some instances almost complete replacement by tourmaline has taken place. A typical thin section of the altered rocks shows an association of tourmaline and quartz with accessory muscovite, iron oxide, apatite and biotite. The tourmaline shows strong pleochroism from pale pink to very dark olive green. Most of the grains show very dark blue-green cores and are generally riddled with quartz inclusions.

Boolaloo Granodiorite

The Boolaloo Granodiorite is an irregularly shaped body with an outcrop of approximately 255 square miles. It is the largest of the granitic masses in the Wyloo Sheet area but may eventually prove to be smaller than the Kilba body when the latter is fully mapped.

In hand specimen the rock is grey-white and speckled with biotite flakes. The quartz is generally a light grey and the feldspar a pale yellow-green.

A typical sample consists of quartz, plagioclase, microcline and biotite with accessory muscovite, apatite, zircon, tourmaline and secondary chlorite, epidote and sericite. Strain extinction is commonly developed in the quartz, which frequently has crystallised into a mosaic of small grains. The microcline is fresh and slightly perthitic, and is subordinate to the plagioclase. The latter has a composition of An_{35-40} and is largely replaced by a fine-grained aggregate of sericite and granular epidote. The biotite is a dark brown to red-brown variety frequently with abundant inclusions of sphene and zircon, surrounded by pleochroic haloes. It almost always shows various degrees of chloritisation. Epidote is often closely associated with the biotite suggesting that the former is replacing the latter. The rock may be termed a biotite granodiorite.

Variations in the microcline/plagioclase ratio occur. It is not known if these are local variations due to differentiation in the granite or if they represent discrete intrusions.

One example shows included half inch areas of a medium to fine-grained assemblage of plagioclase, muscovite and biotite with very rare quartz. It may represent a small syenitic differentiate.

Other larger areas of unknown extent include a tonalite and a nearby adamellite. Apart from the ratio of potash feldspar to plagioclase, the mineralogy of the rock types is similar.

The effects of shearing are often in evidence. An example of a sheared granodiorite occurs towards the western margin of the body some 10 miles northwest of Boolaloo Homestead. The rock shows a pronounced orientation of the biotite and a tendency towards differentiation of the constituent minerals into monomineralic bands.

Occasional aplite veins cut the granodiorite. These carry quartz, fresh microcline and variable tourmaline, partially chloritised biotite and traces of muscovite, apatite and opaques. Plagioclase is rare or absent. The tourmaline is very dark olive-green with blue-green centres. Rarely, a brown tourmaline is present in parallel intergrowth with the dark olive-green variety.

Xenoliths in the Boolaloo Granodiorite are a common feature and usually consist of well-rounded mafic bodies from one to 12 inches in diameter. Examples up to 8 feet in diameter are known but are very rare. The vast majority are even textured and fine-to medium-grained though rare examples have been noted with small white feldspars. Very rarely, near Mt. Hubert, there are xenoliths of banded quartz-cordierite rocks.

Nine miles north of Boolaloo Homestead, one example of the xenoliths in the granite of that region consists of fine-grained quartz and chlorite with accessory epidote, sphene and muscovite. The chlorite is bright green, shows anomalous purple interference colours and is closely associated with the epidote and sphene. Oval patches of sericite, probably after plagioclase, are present. The rock was probably originally a feldspathic greywacke.

Another example from the same general locality consists almost entirely of small flakes of medium-brown biotite and a smaller amount of blue-green hornblende with accessory quartz, calcite, sphene, epidote and sericitic patches probably after plagioclase. It may originally have been a dolomitic shale.

From the same locality another xenolith consists of plagioclase and hornblende with accessory biotite, opaques and traces of chlorite. The plagioclase is a calcic labradorite with somewhat more calcic cores. It shows well preserved ophitic texture. Oscillatory zoning is present in the few larger plagioclase phenocrysts present. The hornblende displays ragged crystal outlines, carries frequent enclosures of biotite and is sometimes sieved with quartz granules. The texture and composition indicate that the rock was originally basaltic.

Examples of reaction between xenoliths and enclosing granite are numerous. One basic xenolith with an assemblage of labradorite, hornblende, and pale-brown biotite shows a decrease in the hornblende content and a development of green biotite at the granite contact. In the granite itself, no hornblende is present and the biotite is a very dark-brown variety with abundant pleochroic haloes surrounding small zircons. In another xenolith of similar mineralogy, biotite increases both in amount and grain size at the contact, where it is sometimes seen in vermicular intergrowth with quartz. Small laths of labradorite similar to those in the xenolith are present in the contact region and extend a few millimeters into the granodiorite where they are surrounded by more sodic plagioclase. Mafic zones in the granite immediately surrounding xenoliths are not uncommon and testify to a certain amount of assimilation.

Kilba Granite

The Kilba Granite occupies a minimum area of 75 square miles in the Wyloo Sheet area. It probably extends to the west of Nanutarra and may also be continuous with the isolated granitic outcrops west of Parry Range. It intrudes metamorphosed Ashburton Formation rocks with strong discordance in the southwest where long thin apophyses of the rock penetrate the adjacent schists. Xenoliths of country rock are present in the mass but are not common; they are composed of mica schists identical to the nearby Ashburton Formation schists.

The Kilba body is a composite intrusion with two main facies: a medium-grained one, forming the bulk of the intrusion, and a porphyritic facies. Migmatites and gneissose granites are known along the western and southern contact regions; they possibly represent an early phase of instrusion. The distribution of these and the relation of the granite to the surrounding schists is shown in Plate 18.

In thin section the medium-grained facies, a muscovite-biotite granite, consists of subhedral laths of plagioclase with interstitial quartz, microcline, muscovite and biotite. The plagioclase, An_7, occasionally shows rims with more sodic composition. Rounded inclusions of quartz are present and very slight sericitisation has taken place. The mica flakes tend to be closely aggregated. Zircon inclusions are common in the biotite, but were not noted in the muscovite.

The porphyritic facies is similar, but carries euhedral microcline crystals up to three inches long usually exhibiting both cross-hatched albite-pericline and simple carlsbad twinning. A preferred long-axis orientation of the phenocrysts is a common feature. There is a general northerly trend modified near the contacts. Measurements were made in several places of the horizontal directional component and histograms constructed (Plate 19).

The relationship between the porphyritic and medium-grained facies is not fully understood. In the northeast of the porphyritic area, the abundance of phenocrysts decreases rapidly and one rock apparently grades into the other. In the extreme south the phenocrysts become smaller and poorly oriented, and the rock grades into the medium-grained facies, which forms the contact.

Quartz veins and pegmatites are rare in the granitic mass, but are more frequent in the marginal rocks. Most of the quartz is barren, but malachite and galena mineralisation was noted in a quartz reef developed at the contact of the granite and the country rock two and a half miles southeast of Mt. Alexander. Some 2½ miles south-southeast of Mt. Alexander abundant small crystals of beryl were found in a small pegmatite, with associated muscovite and dark brown triplite.

CONTACT EFFECTS

Contacts are not generally well exposed but, where seen, were found to show much variation.

On the western slopes of Mt. Alexander thin muscovite granite dykes intrude the metasediments. The contacts are sharp and show no reaction. Two and a half to three miles south-southeast of Mt. Alexander, the granite is probably responsible for the small amount of tourmalinisation which has affected nearby orthoquartzite. In the same general locality, a small roof pendant of tremolite marble shows a patchy development of very coarse grey-white tremolite blades along the contact and joint planes in the marble. This is a similar effect to that noted in a larger tremolite marble roof pendant 8 miles south-southeast of Mt. Alexander though here it is more pronounced. A small pebble of garnet-diopside rock was found in the immediate vicinity, but no skarns were found in situ. Abundant apophyses of the granite cut the marble and the granite carries many xenoliths of marble and amphibole schist, suggesting that stoping has to some extent been an active process in the emplacement of the Kilba Granite.

Apart from these occurrences, the Kilba Granite does not produce much contact alteration. Most of the contacts visited were sharp.

Exposures to within a few inches of the contact of the Boolaloo Granodiorite with the Ashburton Formation at Boolaloo Homestead consist of brown quartz-muscovite schists typical of the Ashburton Formation of this area. It is cut by quartz veins carrying occasional aggregates of pink andalusite crystals up to 1 inch across and 4 inches long. A vein of andalusite in micaceous schist has been recorded near the granite contact about 5 miles southwest of Mt. Black (Black Hill) (Talbot, 1926, p. 46).

On the eastern side of the Boolaloo Granite, 5 miles northeast of Boolaloo Homestead, and extending intermittently for some 14 miles southward is an area of cordierite and andalusite-rich rocks. These are generally well banded, hard and glassy in strong contrast to the more friable and well-cleaved Ashburton Formation elsewere. There is little doubt that these rocks are metamorphosed Ashburton Formation sediments which have been contact metamorphosed and metasomatised by the granite. Their more compact nature has preserved them from some of the effects of the

Ophthalmian Fold Period and they consequently exhibit a different air photo-pattern from the more normal Ashburton Formation. More work on these rocks is being undertaken.

Stoping has also been effective in the emplacement of the Boolaloo Granite. Evidence is readily available on the northeast of Mt. Hubert, where abundant granite veins cut the country rock of cordierite and andalusite-rich rocks. Fragments broken off have become rounded and in the neighbourhood of the contact are generally surrounded by a thin zone of mafic granite, suggesting gradual assimilation of the xenolithic material by the granite.

There is an unusual type of contact phenomenon some 10 miles north of Boolaloo Homestead. The Ashburton Formation here consists of strongly cleaved dark-brown quartz-mica schist with occasional very hard fine-grained bands of slightly micaceous feldspathic sandstone. The schist is cut by many quartz veins.

At the contact is developed a pale-blue medium-grained rock with abundant rounded or oval areas of bluish quartz up to half an inch in diameter. A similar rock is developed in the schists as apparently isolated pods and veins within 50 yards of the contact. In thin section, the rock is composed of a very fine-grained mylonitised groundmass of quartz and potash feldspar with small laths of biotite and some muscovite. Set in this matrix are oval aggregates of biotite, quartz mosaic and altered plagioclase. The biotite shows fragmentation at the edges and has frequently been drawn out into long trails. Generally the plagioclase shows a rounded sericitised core surrounded by a thin rim of relatively fresh (?) albite with, in contrast to the core, a tendency towards a euhedral outline. Oscillatory zoning is noted in the rim. The rock probably developed as a contact porphyry and was subsequently sheared. The shearing has not affected the nearby granite and probably ended before the complete solidification of the rock—hence the euhedral rim to some of the plagioclase grains. It is not impossible that the rock was injected as a crystal "mush".

ECONOMIC POSSIBILITIES

Galena was seen in a quartz vein at the contact of the Kilba Granite near Mt. Alexander. It has been worked some years ago on a very small scale. The workings include a pit 20 feet deep which was abandoned on account of the prevailing lead price. It appears that there is a genetic connection between the granite and the development of the galena. In the Wyloo Sheet area lead is known from several localities, among them the Silent Sisters deposit, some 48 miles southeast of Boolaloo. Here, galena occurs in veins in dolomite in the Wyloo Group. The galena has been dated at 1,700 m.y. ± 150 m.y. (Leggo and others, 1965); this age is close to that of the Boolaloo Granodiorite.

The association of Boolaloo Granodiorite with cordierite-rich rocks, probably partly metasomatic, resembles that described from Sweden by Geijer (1963). He stresses the close genetic connection between granite emplacement with sulphide mineralisation and accompanying magnesium metasomatism, this latter being responsible for the production of extensive bodies of cordierite-bearing mica schists. Some of the Swedish sulphide ores are thought to have developed "in front of the granite" (Geijer, 1963, p. 117). The cordierite-rich rocks near the Boolaloo Granodiorite show evidence of development before emplacement of the main mass. Grains of sulphide minerals have been found in the cordierite rocks, but no large masses located.

In view of the similarities to the Swedish examples, a prospecting programme for sulphides along the eastern margin of the Boolaloo Granodiorite is recommended. This region is poorly exposed, being largely covered with alluvium and river gravels associated with the Ashburton River.

There seems little possibility of beryl occurring in sufficiently large concentrations in the pegmatites to be of value.

CONCLUSIONS.

The granitic rocks of the Wyloo Sheet area are divisible into two groups: a mafic biotite granodiorite suite to the east and a leucocratic muscovite granite to the west. Both have been intruded during the waning phases of the Ophthalmian Fold Period. The biotite granodiorite suite is probably older, as it shows more effects of shearing than the muscovite granite.

Xenoliths are common in the biotite granodiorite but relatively rare in the muscovite granite. Those present in the latter closely resemble the adjacent country rock. This is not generally the case with the Boolaloo Granodiorite suggesting that incorporation of these xenoliths took place at a much greater depth than their present position. Evidence of stoping is present in both the Kilba Granite and the Boolaloo Granodiorite. The cordierite-rich rocks near Mt. Hubert are probably part of an early aureole which the granodiorite has later partially stoped and assimilated.

Intrusion has taken place in an area of general northerly trending structures where noticeable increase in the grade of metamorphism has occurred. It is also the area where migmatites are recorded.

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BRECCIAS ASSOCIATED WITH THE PROTEROZOIC BANGEMALL GROUP, NORTH WEST DIVISION

by J. L. Daniels

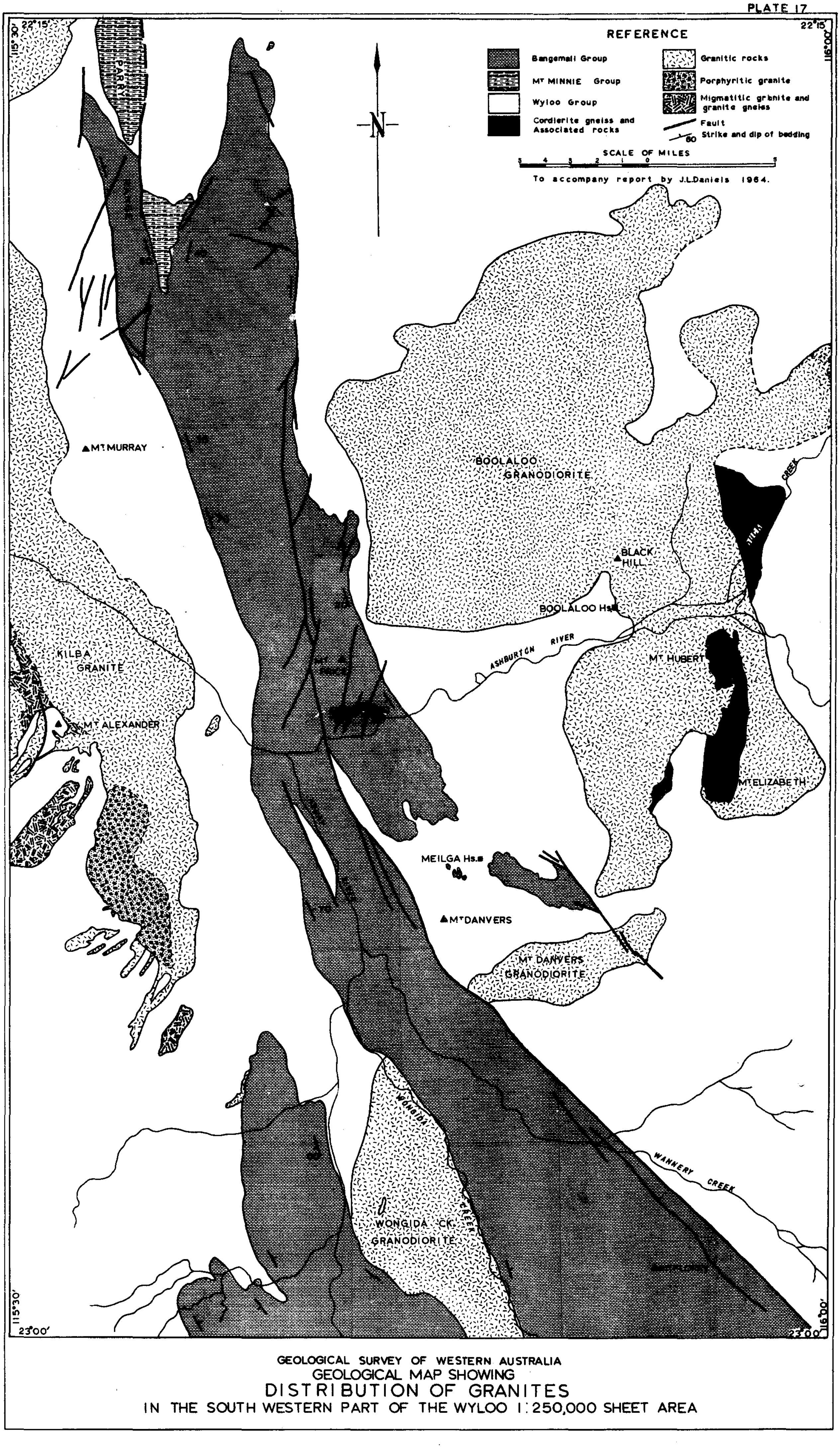
ABSTRACT

Breccias composed of fragmented sedimentary rocks are common in the Proterozoic Bangemall Group between the Parry Range and Mt. Florry. The fragments forming the breccias are almost entirely composed of Bangemall Group sediments. Three types of breccia are recognised and described: sedimentary, tectonic and diapiric.

They probably originated during a protracted series of land movements associated with the Edmundian Fold Period and are probably different results of the one process.

INTRODUCTION

During regional mapping of the western half of Wyloo and the northern part of Edmund Sheet areas (SF/50-10 and SF/50-14), comparatively abundant breccias were found closely associated with the youngest Proterozoic rocks of the area, the Bangemall Group. The breccias are coarse to extremely coarse, fragmented and poorly sorted sedimentary rocks usually forming a distinctive



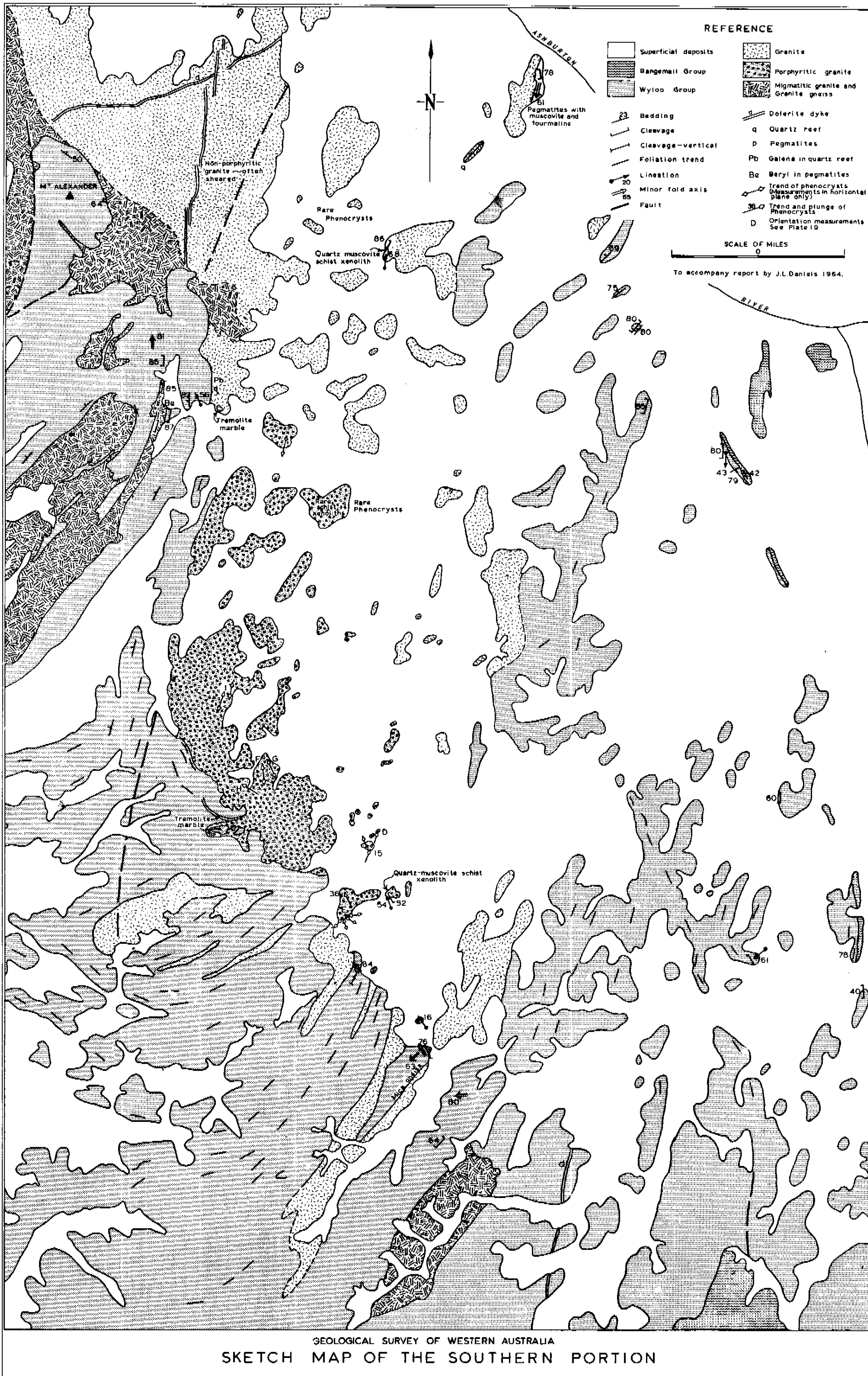
GEOLOGICAL SURVEY OF WESTERN AUSTRALIA

GEOLOGICAL MAP SHOWING

DISTRIBUTION OF GRANITES

IN THE SOUTH WESTERN PART OF THE WYLOO 1:250,000 SHEET AREA

8666

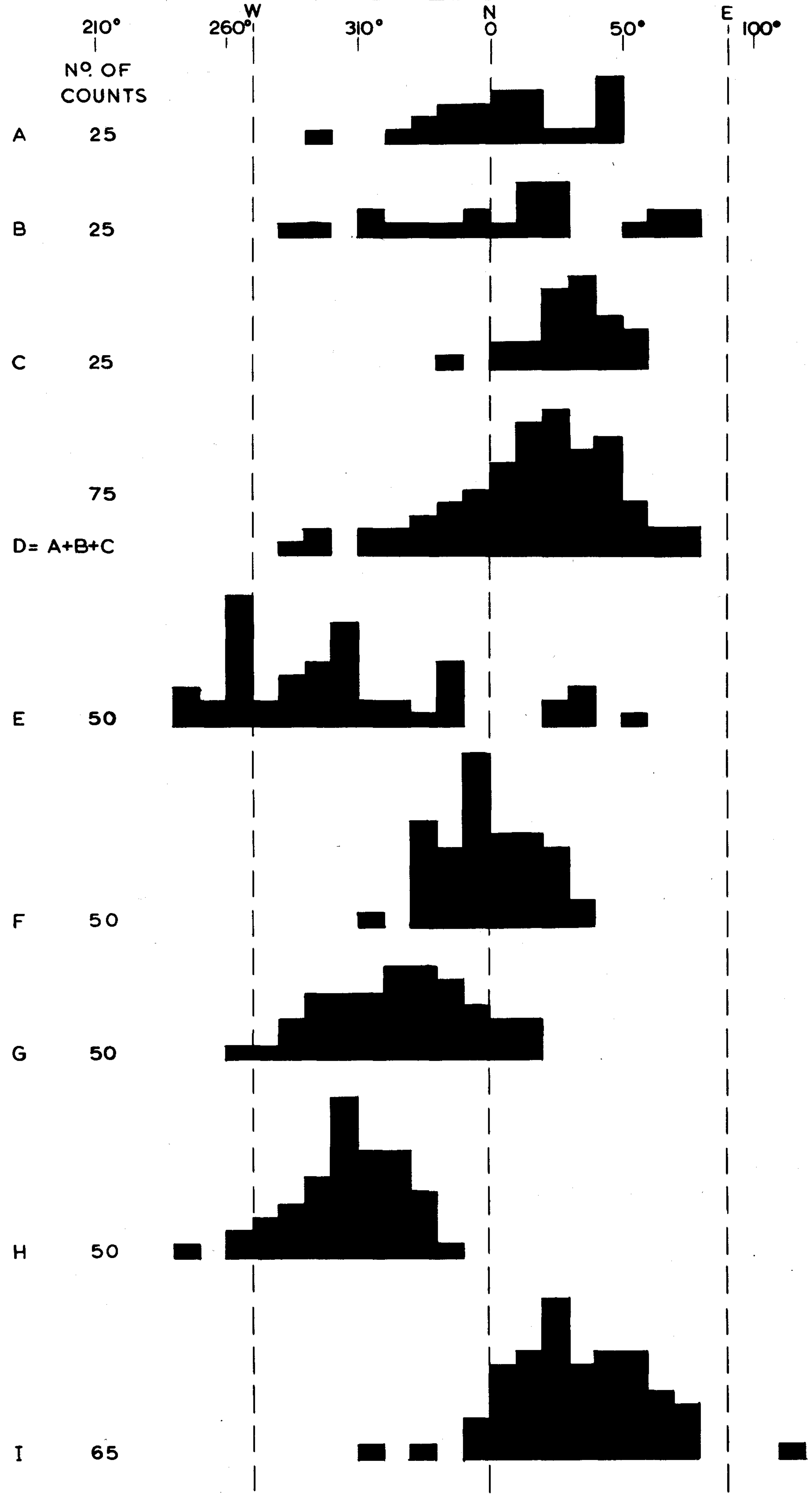


GEOLOGICAL SURVEY OF WESTERN AUSTRALIA

SKETCH MAP OF THE SOUTHERN PORTION OF THE KILBA GRANITE

PLATE 18

8667



HISTOGRAMS SHOWING
ORIENTATION OF FELDSPAR LATHS, MEASURED IN THE HORIZONTAL PLANE, IN THE KILBA GRANITE

8665

topography. Hills composed of the breccias are generally craggy with smooth lower slopes covered by secondary breccia debris. In consequence, field relations of the primary breccia to the rest of the Bangemall Group sequence are difficult to interpret. On many of the lower hills, considerable doubt exists as to whether one is dealing with a primary breccia or a recent talus deposit.

Three main types of breccia have been recognised and decribed according to their origin:

(a) sedimentary breccia
(b) tectonic breccia
(c) diapiric breccia.

It is probable that they are genetically connected even though a time difference exists between the sedimentary variety and the others. The former is of Bangemall Group age while the others are younger and probably contemporaneous with the post-Bangemall, Edmundian Fold Period and associated faulting. (Halligan and Daniels, 1964.)

On a regional basis this fold period has been most effective in deforming the Bangemall Group sediments between the Parry Range, the area a little to the east of Mt. Florry, and southwards into the Edmund Sheet area (see Plate 17). Further to the east, dips are generally shallower and strong folding is absent. It is in the strongly folded areas, especially between the Parry Range and Mt. Florry that the breccias are developed.

All the breccia probably originated during a protracted series of land movements associated with the Edmundian Fold Period. Movement is thought to have started during the deposition of the Top Camp Dolomite, the basal part of the Bangemall Group, and probably continued intermittently, culminating in the production of isoclinal and recumbent folds near Mt. Florry.

SEDIMENTARY BRECCIA

Sedimentary breccia is best developed at Mt. Price and the adjoining ridge, which runs northward for 2 to 3 miles, a haphazard arrangement of angular sedimentary fragments ranging in size from a fraction of an inch to large blocks several feet across. The breccia is approximately 200 feet thick.

The principal rock types involved are silicified algal dolomite and current-bedded sandstone. On the whole, little mixing of the two varieties is seen and large masses are composed dominantly of fragments of one variety, with only small amounts of one in the other.

The lower part of Mt. Price is composed dominantly of brecciated, silicified algal dolomite, while the crest is almost entirely made of current-bedded sandstone fragments.

The silicified algal dolomite is milky white and composed dominantly of silica. Iron staining and differential weathering accentuate the original structure of the rock which was primarily composed of either close-packed, cone-shaped algae with diameters up to 4 inches, or undulating sheets exhibiting a series of small flutes in vertical section. None of the supposed original dolomite remains.

The current-bedded sandstone is light grey, weathers to pale brown and frequently develops a porous texture.

In the breccia in one of the foothills of Mt. Price, extremely rare well-rounded orthoquartzite boulders up to 12 inches across have been found.

The breccia at Mt. Price occupies the axial region of a syncline. It overlies thin-bedded, current-bedded, sandstone in the south, but overlies dolomite further to the north. Isolated dolomite "stacks" surrounded by breccia occur on the south side of Mt. Price.

The stratigraphic sequence near Mt. Price consists of the following:

Top breccia
dolomite
sandstone
dolomite
Unconformity
Ashburton Formation

The lower dolomite is divisible into several units, one of which carries abundant silicified algal dolomite bands which are apparently identical with the dolomite fragments in the breccia. Similar algae are not present in the upper dolomite. Overlying the basal dolomite is a series of sandstones and quartzites, almost always showing well developed current-bedding. They vary from grey to light brown and weather to a porous, cindery texture in most places. These characters compare closely with those of the current-bedded sandstone fragments in the breccia.

These comparisons of lithology suggest that the breccia at Mt. Price has been derived from lower stratigraphic units of the Bangemall Group. In order for this to take place, two possible means may be considered: diapirism and sedimentation.

No evidence for diapirism was found near Mt. Price. Mapping shows that the breccia rests on different stratigraphic units at different places, but in all cases the observed contact was conformable for short distances (*i.e.*, the length of the outcrop) with the underlying bedding.

The presence of rare, water-worn boulders of quartzite suggests that, during transportation and deposition of the breccia, surface material was incorporated. It is difficult, if not impossible, to conceive how water-worn boulders could be incorporated in a diapiric mass when no evidence for the presence of similar boulders is forthcoming from the underlying rocks. A basal conglomerate is developed, mainly along the western margin of the Parry Range, but although it is absent in the eastern outcrop it is nevertheless a distinctive type, composed of much smaller vein-quartz pebbles up to two inches diameter that could not be the source for the boulders.

The paucity of rounded fragments and the low degree of mixing of the two main types suggests that erosion, transportation and deposition took place very rapidly.

I envisage two possible processes which may be capable of supplying the necessary conditions: (a) slumping, possibly initiated by faulting, and (b) rapid talus development along the line of a fault escarpment.

At present the evidence available is not sufficient to decide between these two possibilities. However it is almost certain that faulting played a major role.

TECTONIC BRECCIA

From a point just west of Mt. Danvers to the Mt. Florry region, for a distance of 20 miles, breccia is very common, forming long ragged ridges in a steeply dipping sequence of sandstone and shale. Close examination reveals that some of the sandstone bands have been brecciated intermittently along their outcrops. The breccia consists of angular fragments of sandstone up to 8 feet across in a very fine-grained quartzose groundmass. Sericite is present in small quantities. Iron staining with associated salt encrustations has been noted. Along strike the breccia passes into undisturbed sandstone.

The breccia has developed parallel to a major fault zone which, along most of its length, throws the upper part of the Bangemall Group against the Ashburton Formation. This fault is also parallel to the regional fold trends. At one point the fault zone cuts a Proterozoic granite which has developed a strong gneissose texture over a considerable width, proving that intense shearing accompanied the faulting.

There is no doubt that this breccia has remained, more or less, *in situ* and has developed as a direct consequence of the proximity of this major fault zone.

In the Kookabinah Valley about 12 miles southeast of Mt. Florry, strongly folded orthoquartzite is abundant. In the cores of the anticlines, and always parallel to the fold axes, a coarse brecciated zone or band is commonly developed. The breccia is composed of orthoquartzite fragments and confirms the relationship, in this area, of folding with brecciation.

DIAPIRIC BRECCIA

Approximately 2 miles northwest of Mt. Florry, breccia masses, varying from 50 to 200 yards across, are moderately abundant. They consist of small, angular sandstone fragments. In one locality, a horseshoe shaped "dyke" of breccia surrounds bedded dolomite, which elsewhere overlies sandstone. The sandstone closely resembles that found in the breccia and is regarded as the source rock. The contacts are vertical and the edge of the dolomite is partially brecciated. This appears to be the only good example of diapirism in the area.

It is possible that the intense folding which has affected the Mt. Florry region produced breccia in anticlinal axial regions and, where the forces were intense enough, injected this brecciated material into a higher stratigraphic unit.

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NOTES ON A MOUND SPRING ON MARDIE STATION, NEAR CAPE PRESTON

by I. R. Williams

A hill on Mardie Station, midway between Onslow and Roebourne in the North-West Division, was discovered to be an active mound spring during geological mapping of the Yarraloola 1 : 250,000 Sheet (SF/50-6).

Known as Mt. Salt (Western Australian Lands Dept. Reference Point 11; lat. 21° 4′ 42″ S., long. 115° 58′ 22″ E.), the mound rises from the coastal marsh 8 miles north of Mardie Homestead. It lies approximately 1½ miles inland from the shore and ½ mile seawards from the edge of the coastal plain.

Approach by vehicle is by way of a mill track to Hilda Well, thence due north for 2½ miles to a point opposite the mound spring on the edge of the coastal plain. It is necessary to walk the remainder of the distance.

The mound spring deposit is roughly elliptical in plan outline, the long and short axes being 320 yards and 180 yards respectively. The long axis trends 295 degrees, in which direction are aligned two coalescing domes. The eastern dome rises approximately 25 feet above the tidal flats; the western dome is lower, reaching 18 feet. Both domes rise above the general level of the nearby coastal plain. At present, the active sections of the mound spring are mainly confined to the western dome. The water makes its appearance immediately below the summit in a series of small basin-like depressions. From these it flows down the side of the dome forming numerous small rimstone pools and depositing massive flowstone. There is also seepage from the base of the mound. Many of the basins contain a fine reddish flocculate thought to be iron oxide or hydroxide; iron-stained flowstone is also common. The twin domes are surrounded by a gently dipping platform stretching for several hundred yards down to the tidal mud flats which is built up by the spring water, and containing many shallow basins up to 5 feet in diameter.

The mound spring has been built up almost exclusively by calcareous tufa. Microscopically it consists mainly of calcite with patches and thin bands of iron hydroxide. Recrystallisation is apparent in the older tufa collected from the extinct easterly dome, and some of the larger crystals show relict accretionary cone-in-cone structures outlined by the iron hydroxides. This mode of growth indicates one of the possible methods by which the mound spring has been built up.

Four samples, two from the older weathered tufa and two from recently precipitated flowstone, were submitted to the Government Chemical Laboratories for total rock analysis. The results confirmed the microscopic observation of a high calcium carbonate content. The maximum percentage, 95.1, was obtained from fresh flowstone. The percentage of ferric oxide is related directly to the weathering of the rock, the water containing only a small amount of soluble iron. The remainder was made up of magnesium carbonate (generally low and roughly in the proportion of 1 : 30 calcium carbonate) with insoluble material, consisting of detrital quartz and clay material, and water-soluble salts, including sodium chloride. The sulphate content was negligible.

The water issuing from the springs is very salty to taste; a water sample was not collected. It is possible that the salt content is mainly derived from the nearby ocean and the possible leaching of marine sediments beneath the mound spring, thus contaminating the rising water, which is assumed to be rich in carbonate. At present, the evaporation rate is high, causing rapid deposition of the calcium carbonate. The greater solubility of the sodium chloride causes it to remain in solution until the final stages of evaporation are reached at the base of the mound.

Because Spence (1962) mentions Mt. Salt as being a fairly intense radioactive anomaly, a hand specimen of fresh flowstone was tested and found to be slightly radioactive. The source of the radioactivity is not known at present but it has been suggested by D. L. Rowston (pers. comm.) that it may be due to potassium-40 (contained in such minerals as sylvite), and which emits gamma rays. Senftle (1948) has recorded evaporites from elsewhere which have low radioactivity.

The formation of mound springs depends on two main points:

(a) The existence of a suitable aquifer containing sufficient quantity of water and the necessary hydrostatic pressure

(b) A path within the sediments to allow the artesian water to escape to the surface.

Geological mapping carried out in the surrounding region indicates the presence of a basin which rapidly deepens westwardly and lies beneath the mound spring. The basin is known to contain sediments ranging in age from Lower Cretaceous to Recent. The edge of the basin runs north—south, and the overlap on the Proterozoic basement is well exposed 20 miles southeast of the mound spring. It is suggested that the overlap of these sediments has led to the exposure of suitable intake beds which draw water from the westerly flowing drainage systems (for example the Fortescue River) which are known to contain carbonates derived from the Proterozoic sediments.

Apart from the strong east trend of the spring, no information has been obtained as to the nature of the spring outlet.

The age of the spring is not certain, although it appears to have existed before the eastward retreat, by recent erosion, of the coastal plain. The overall slope of the mound has since been modified by the continual addition of material.

The important point to arise from the study of the mound spring is that it supplies evidence of an artesian basin beneath the coastal plain with permeable beds capable of acting as aquifers; an important factor in the search for oil.

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REGIONAL METAMORPHISM IN THE LAMBOO COMPLEX, EAST KIMBERLEY AREA

By I. Gemuts

ABSTRACT

Regional metamorphism occurred in the East Kimberley area, Western Australia, during the Archaean. Greywackes, shales, dolomites, calcareous sediments and mafic igneous rocks were metamorphosed to assemblages ranging from the low greenschist to granulite facies. The metamorphism culminated with the intrusion of anatectic granites. Four metamorphic zones can

be recognised by changes in the absorption colours in the Z direction of calcic amphiboles present in metamorphosed mafic igneous rocks.

INTRODUCTION

These preliminary remarks on the regional metamorphism in the Lamboo Complex rise out of current investigations by the Geological Survey and the Commonwealth Bureau of Mineral Resources in the Kimberley District. The location of the area investigated is shown in Plate 20. Much of the information in the following pages has already been outlined in Bureau of Mineral Resources unpublished reports (Smith, 1963: Dow and Gemuts, 1964; Dunnet and Plumb, 1964; Dow and others, 1964). Dow and others (1964) discussed briefly the regional metamorphism of the East Kimberley area and subdivided the region into five metamorphic zones. I have slightly modified their original zonal subdivision.

M. V. Bofinger of the Bureau of Mineral Resources is studying the age of the rocks from the area. His initial results are used in this report.

I wish to acknowledge gratefully my reliance on the observations of other geologists in the field parties as it is largely on these observations that the present interpretation is based.

The name Lamboo Complex was used by Matheson and Guppy (1949) and defined by Guppy and others (1958) to include granite, granitic gneiss and metasediments. Traves (1955) used the name to include all the granitic rocks in the East Kimberley area, but excluded the metasediments. I prefer the original definition and have included in the Lamboo Complex all the high-grade metamorphics, as well as the associated basic and acid plutonic rocks. This approach is justified since there are areas where it is impossible to delineate a boundary between igneous and metamorphic rocks.

The Lamboo Complex forms a belt nearly 200 miles long and about 30 miles wide, between Mount Hawick in the south, (off Plate 20) and Pompeys Pillar to the north. Further north the complex is covered by younger sediments with the exception of inliers of granite near the Halls Creek Fault.

The metamorphic rocks of the Lamboo Complex are called the Tickalara Metamorphics (Dow and Gemuts, 1964) and make up about one third of the complex. Some irregular roof pendants of metasediments in granite in the southern part of the complex are also referred to the Tickalara Metamorphics. Anatectic gneissic granites intruding the metamorphics are thought to be derived by fusion and melting of the metamorphic rocks.

To study the regional metamorphism in the Lamboo Complex it is necessary to consider also the Halls Creek Group. This group has been subdivided into the following units: Ding Dong Downs Volcanics; Saunders Creek Formation; Biscay Formation; and Olympio Formation (Smith, 1963). The Tickalara Metamorphics are regarded as the metamorphosed equivalents of this group.

The relevant geology is sketched in Plate 20. In the sections that follow, the structural setting of the Lamboo Complex is described first, then the main varieties of metamorphic rocks in the Tickalara Metamorphics and their distribution; and after this there is a discussion in which four metamorphic zones are outlined and the facies of metamorphism are recognised. Also, metasomatism is considered and the discussion concludes with a brief geological history.

STRUCTURE

The major structural unit of the East Kimberley area is the Halls Creek Mobile Zone (Traves, 1955), a belt of intensely deformed crystalline rocks, which includes the Tickalara Metamorphics. This zone lies between two stable blocks (the Sturt and Kimberley Blocks). It is a zone of great lateral and vertical movement, whose magnitude and extent in time are not yet precisely known; all the folding in the Tickalara Metamorphics may be assumed to be connected with the movement.

FOLDING

South of the Ord River, folds in the Tickalara Metamorphics have steep northerly plunging axes. The anticlines have overturned eastern limbs; and the synclines are sheared out along faults branching from the Halls Creek Fault. The major fold axes and axial planes trend north-northeast. These folds are very similar to the axial-plane cleavage folds in the Halls Creek Group. The regional structure is disturbed to the west by intrusive granites and numerous shear zones.

North of the Ord River, the structure is very complex with both ptygmatic and isoclinal folds. Transposition of folded layers and plastic flow have been the dominant processes of deformation. Flowage phenomena are especially spectacular in marble bands, which have flowed plastically; whereas intercalated gneiss and amphibolite layers are shattered and disoriented.

In the least deformed areas, minor folds are generally paralleled by steeply plunging lineations caused by elongation of metamorphic minerals. The orientation of these lineations is constant over large areas. However in the Black Rock Anticline and in the metamorphics enveloping the basic sills at McIntosh Hills, there is a later strain-slip (crenulation) cleavage developed, cutting across and deforming the earlier folds and their accompanying lineations. In these areas there is a maximum development of knotted schist and pencil gneiss.

In the migmatites the plunges of dominant lineations (formed by alignment of acicular sillimanite and of biotite laths) are most variable. Detailed structural analysis would be needed to unravel the structural complexity.

FAULTING

The eastern boundary of the metamorphics is the Halls Creek Fault; it strikes north-northeast and extends over a distance of 250 miles. The fault has a large vertical component, with downthrow to the east. And it also has a large horizontal component; in the south it appears to have displaced the Halls Creek Group rocks horizontally at least 16 miles, west block south. With the exception of this fault and its smaller subsidiary faults there are no other large faults affecting the Tickalara Metamorphics.

TICKALARA METAMORPHICS

The Tickalara Metamorphics include a great variety of metamorphic rocks ranging in grade from low amphibolite facies in the south to granulite facies in the north. The following rock types have been recognised: schist, paragneiss, orthogneiss, calc-silicate, amphibolite and basic granulite. The boundaries between many of the types are gradational and generally impossible to map, but calc-silicate and amphibolite bands have been picked out and these are valuable markers throughout the metamorphics.

MICA SCHIST

Mica schist resulting from low-grade regional metamorphism is interbedded with calc-silicates and amphibolite, both on the eastern flank of the Black Rock Anticline and as a narrow belt northwards from Armanda River to Sally Malay Well along the Halls Creek Fault.

The dominant rock types are quartz-muscovite schist and quartz-biotite schist; garnet, andalusite, chloritoid and kyanite are locally present.

Crenulated schists, containing staurolite and a little sillimanite, occur in the core of the Black Rock Anticline; as a narrow band east of the anatectic granites between the Ord River and Turkey Creek Post Office, and west of McIntosh Hills. Pods of epidote-rich quartzite are present in these rocks.

PARAGNEISS

Paragneiss extends in a belt 20 miles wide and 100 miles long from the Armanda River in the south to Bow River in the north. To the east it is bounded by the Halls Creek Fault; and late granites intrude the gneiss to the west.

The mineral assemblages of the paragneiss change from quartz-feldspar-biotite to garnetiferous types in the south and ultimately in the north into rocks with sillimanite and cordierite.

Low-grade Paragneiss

Quartz-feldspar-biotite gneiss is the dominant rock type in the low grade paragneiss. It is intertongued with amphibolites, calc-silicates and ultrabasics. The gneiss is banded, with dark and light layers. The minerals in the dark bands are mainly biotite and hornblende, and in some cases biotite and garnet. Normally these mafic bands are not continuous but form schlieren which are strung out parallel to the foliation. The light layers have a granitic composition and a porphyroblastic texture that varies from medium to coarse grained.

High-grade Paragneiss

Close to the anatectic gneissic granites in the region between Turkey Creek Post Office and Violet Valley, the paragneiss is migmatitic and granulitic with good evidence of lit-par-lit injection of granitic fluids into metasediments. These high-grade metamorphic rocks are represented by assemblages rich in garnet, sillimanite and cordierite. The banding is not laminar or continuous and most bands are contorted and swirled in a complex fashion. The quartzo-feldspathic parts of the migmatite form discontinuous lenses and streaks as well as small rootless folds and boudins, all set in mafic bands. The bands are composed of sillimanite, biotite, garnet and cordierite in varying proportions. Interlayered with the migmatite are stringers of basic granulite.

CALC-SILICATE ROCKS

Marble and associated calc-silicate rocks crop out in a belt which extends for 100 miles from Halls Creek to Mount Pitt. In the south, near Armanda River, there are deformed roof pendants of calc-silicates (skarns) within granitic and basic rocks of the complex. To the north, calcareous rocks are interfoliated with amphibolite, knotted schist, and gneiss in the following areas: the Black Rock Anticline, on the margins of the McIntosh Hills, and along the Halls Creek Fault. Four continuous marble beds and a number of discontinuous beds have been mapped in the Black Rock Anticline. To the west of this area, where the structure is more complex and the metamorphism is of higher grade, the calc-silicate bands are truncated by granite and by amphibolite.

Skarns in the Armanda River Area

Near Armanda River, there are roof pendants of calc-silicates which are interlayered with other metasediments and intruded lit-par-lit by granite. The calc-silicates retain traces of bedding. The most common rock type consists of: coarsely granular green diopside or hedenbergitic pyroxene; pink garnet; light green epidote; and a little scapolite; all intergrown with fibrous white decussate wollastonite.

The calc-silicates in the Armanda River area have undergone migmatisation and it is difficult to say how much of the silica is original and how much is introduced.

Calc-silicate Rocks in the Black Rock Anticline

Numerous calcareous beds occur in the Black Rock Anticline and in the vicinity of Dougalls Bore. There are both calc-silicates and pure marbles. The marbles are generally white and coarse-grained, but some contain disseminated silicate minerals and others contain calc-silicate bands and blebs which parallel the regional foliation.

The calc-silicates are either massive, or interlayered with marble, amphibolite, gabbro and garnetiferous gneiss. In the massive calc-silicates, pink garnet is associated with green diopside and epidote in varying amounts. In the banded rocks, garnetiferous bands rich with epidote alternate with bands rich in scapolite and diopside.

Relationship with Amphibolites

The calcareous rocks along the Ord River and in the Dougalls Bore area are intimately intercalated with amphibolite. However, at all places where there appeared at first sight to be a graduation between calc-silicates and amphibolites, it was found that the changes were due to tight isoclinal folding. It is possible that some of the amphibolites associated with the calc-silicates have been derived from them.

AMPHIBOLITES

Amphibolites interlayered with metasediments crop out between Dougalls Bore and White Rock Creek Well, in the Black Rock Anticline, on the margins of the anatectic granites and in the McIntosh Hills.

In these areas, the amphibolites are well foliated and are intercalated with gneisses and calc-silicates. They range from foliated dark-green homogeneous, amphibole-rich types to banded amphibolites with bands of quartz and feldspar up to 1 inch thick. This banding is generally parallel to the regional cleavage, but in some areas appears transgressive.

Two suites were noted in the amphibolites. The first is present in a belt to the west of the Halls Creek Fault between Sally Malay Well and Alice Downs Homestead. It contains the following assemblages:

(i) Hornblende-plagioclase-quartz-epidote or clinozoisite-sphene;
(ii) Hornblende-plagioclase-quartz-sphene.

The second suite is present in the higher grade amphibolites close to the margins of the anatectic granites. In it are the following assemblages:

(i) Hornblende-plagioclase-quartz;
(ii) Hornblende-clinpyroxene-plagioclase-quartz.

Association with Pyroxene Granulites

In the Violet Valley region and north of Mabel Downs Station on the western side of the anatectic granites, the metamorphic grade of the amphibolites is higher and they grade into pyroxene granulites. The rocks are dark and massive in hand specimen. They have a grandular fabric and contain pyroxene, although some bands lack pyroxene. The following assemblages were noted:

(1) Hornblende-clinopyroxene-plagioclase-quartz;
(ii) Hornblende-clinopyroxene-orthopyroxene-plagioclase-quartz.

PYROXENE GRANULITES

Pyroxene granulites form dark lenses and bands in the high grade paragneiss between Tickalara Bore and Turkey Creek Post Office. The bands are from inches to miles in length and they pinch and swell along strike. North of Mabel Downs paragneiss wraps around stock shaped bodies. On closer inspection these have been found to be gabbros with margins of pyroxene granulites. Lenses inches in width occur within the migmatites close to the anatectic granites.

In hand specimen the pyroxene granulites are dark green to black. They have a grandular texture, and a rudimentary foliation but no lineation. The foliation is parallel to that of the enclosing paragneiss. The following mineral assemblages were recognised:

(i) Plagioclase - clinopyroxene - quartz - hornblende - garnet;
(ii) Plagioclase - clinopyroxene - orthopyroxene - quartz - hornblende;
(iii) Plagioclase - clinopyroxene - quartz - hornblende;
(iv) Plagioclase - clinopyroxene - cummingtonite - quartz;
(v) Plagioclase - clinopyroxene - orthopyroxene - biotite.

METAMORPHIC ZONES

The Halls Creek Group and the Tickalara Metamorphics can be divided into four broadly defined metamorphic zones based on the change in absorption colour in the Z direction of the calcic amphibole in basic rocks. This follows the principle enunciated by Engel and Engel (1962), that hornblendes undergo systematic changes in colour, composition and density during progressive metamorphism from almandine-amphibolite to hornblende-granulite facies. The change in absorption colour in the Z direction has proved to be consistent with mineralogical changes in other rock types from the area. Zones based on hornblende have been established in other parts of the world by Miyashiro (1958), Shido (1958), Layton (1963), and Binns (1963). The metamorphic zones are not shown on the map, but their distribution is outlined in the descriptions. The zones are considered to be valid although obviously in need of refinement. Further examination of schists and gneisses, paying special attention to biotite, garnet, staurolite and sillimanite appears warranted.

Changes in mineral assemblages with increasing grade of metamorphism in the Halls Creek Group and Tickalara Metamorphics are shown in Table 1.

Table 1

PRELIMINARY OBSERVATIONS OF MINERALOGICAL VARIATIONS WITH INCREASING GRADE OF METAMORPHISM, IN THE HALLS CREEK GROUP AND TICKALARA METAMORPHICS

Rocks	Mineral	Zone A	Zone B	Zone C	Zone D
MICA SCHISTS AND PARAGNEISSES	Quartz	———	———	———	———
	Chlorite	———	———		
	Muscovite	———	– – –	– – –	– – –
	Chloritoid		– – –		
	Biotite		———	———	———
	Garnet		– – –	———	———
	Staurolite			– – –	
	Kyanite		– – –		–·–·–·–
	Andalusite		– – –	———	– – –
	Sillimanite			– – –	———
	Cordierite			– – –	———
	Plagioclase	———	———	———	———
	Microcline			– – –	———
	Hornblende				–·–·–·–
SKARNS AND CALC-SILICATES	Dolomite	———			
	Tremolite	– – –	———		
	Hornblende			rare throughout	
	Cummingtonite				———
	Chlorite	– – –	———		
	Calcite	———	———	———	
	Diopside			———	———
	Epidote			———	
	Garnet			– – –	———
	Scapolite		– – –	– – –	– – –
	Wollastonite				–·–·–·–
	Plagioclase			– – –	———
	Quartz		very rare throughout		
AMPHIBOLITES AND BASIC GRANULITES	Actinolite-Tremolite	Colourless to ———	Pale Green – –		
	Hornblende		Dark Green ———	Green-Brown ———	Light Brown ———
	Cummingtonite				———
	Sphene		———		
	Chlorite	– – –	———		
	Epidote	– – –	———		
	Plagioclase	———	———→	An content increase ———	———
	Calcite	– – –			
	Orthopyroxene				———
	Clinopyroxene			———	———
	Biotite			– – –	– – –
	Quartz		– – –	– – –	– – –

Note : A full line indicates that a mineral is common and abundant ; a broken line indicates that it is common but not abundant; a dash-dot indicates that it is rare. (Arrangement after Miyashiro, 1958).

The four metamorphic zones in the East Kimberley area are:

ZONE A

In this zone amphibole is usually absent, but if present it is actinolite-tremolite forming discrete laths or replacing primary hornblende. Absorption colour in the Z direction varies from colourless to pale green. The rocks in this zone are slightly metamorphosed and include chlorite-muscovite rich greywacke and siltstone (chlorite 1 and 2 zones of Turner, 1938), dolomite, uralitised dolerites and ultrabasic rocks. This zone embraces the Olympio Formation.

ZONE B

This zone is defined by the appearance of common hornblende in subhedral acicular laths arranged either singly or in rosettes. The absorption colour in the Z direction varies from blue green to dark green. In some areas light green hornblende also occurs. Biotite, andalusite, garnet, kyanite and chloritoid schists are associated with calcareous rocks containing calcite and tremolite. The amphibolites contain epidote ahd sphene. This zone embraces parts of the Biscay Formation and the rocks on the margins of the Black Rock Anticline.

ZONE C

Zone C is characterised by acicular hornblende with a green-brown absorption colour in the Z direction. The disappearance of the bluish green tinge marks the transition from Zone B. Clinopyroxene is associated with hornblende in some rocks. There are areas however, where green hornblende persists and without more field information it is impossible to say whether these hornblendes are in Zone B or Zone C.

An indicator of grade in the mica schist and paragneiss is abundant garnet with staurolite and fibrolitic sillimanite. Knotted schist and pencil gneiss predominate in this zone. Calcareous rocks are rich in diopside, epidote and garnet. The amphibolites have no epidote or sphene. This zone occurs south of the largest anatectic granite body and it extends from McIntosh Hills to Tickalara Bore. The core of the Black Rock Anticline also contains rocks of Zone C.

ZONE D

In this zone granular hornblende occurs by itself or in association with an orthopyroxene. The absorption colour in the Z direction is brown or light brown. The paragneiss contains microcline, plagioclase, garnet, cordierite, sillimanite and subordinate kyanite. Marginal to the anatectic granites in the north there is a maximum development of cordierite, biotite and microcline. The calcareous rocks have assemblages containing either wollastonite, diopside and garnet or anorthite and cummingtonite associated with a clinopyroxene. The appearance of orthopyroxene in the amphibolites is a valuable indicator of Zone D. Rocks of this zone extend northwards from Tickalara Bore to Bow River.

METAMORPHIC FACIES

The slightly metamorphosed rocks of the Halls Creek Group belong to the greenschist facies, whereas the Tickalara Metamorphics range from high greenschist to granulite facies. The metamorphic zones can be placed in the following facies of Fyfe and others (1958):

ZONE A

Greenschist facies; quartz-albite-muscovite-chlorite subfacies.

ZONE B

Greenschist facies; quartz-albite-epidote-biotite to quartz-albite-epidote-almandine subfacies.

ZONE C

Almandine-amphibolite facies; staurolite-quartz subfacies.

ZONE D

Almandine-amphibolite to granulite facies; sillimanite-almandine subfacies transitional to hornblende-granulite subfacies.

METASOMATISM

Metasomatism has been an important process in the high-grade metamorphic rocks, and it is usually associated with the late intrusive porphyritic granites or the anatectic granites. Irregular masses of skarn form roof pendants in coarse-grained granite in the southern part of the Lamboo Complex. Garnet, hedenbergitic pyroxene and scapolite in the skarns seem to be pyrometasomatic. Similarly the presence of scapolite and apatite in Zone C can be taken to indicate a metasomatic introduction of silicates and halogens, although these constituents may quite possibly be connate. It appears that water has been one of the main agents in altering some of the calcareous silicate lenses and sheared gabbros to tremolite-talc-serpentine rocks in Zone B.

Close to the anatectic granites, paragneiss has been soaked by granitic fluids forming migmatites. Without doubt this has been accompanied by an introduction of magnesium, potassium and silica into the country rocks. It is evident that without supporting chemical data, the exact nature of the metasomatism involved cannot be indicated.

Metasomatic action, other than that involving water, is not so obvious in the lower grades of metamorphism. Tourmaline is present in the pelites of Zones A and B. In Zone A it is detrital, but in Zone B most probably allochemical. A metasomatic origin is favoured in this zone because euhedral tourmaline forms veins and is usually associated with apatite. This hypothesis is supported by the suggestion of Binns (1963), that tourmaline in knotted schists from the Broken Hill region of New South Wales is metasomatic. And Read (1939) states that: ubiquitous tourmaline in regionally metamorphosed rocks is an indicator of the action of "emanation" throughout all grades.

GENESIS OF THE LAMBOO COMPLEX

The history of the Lamboo Complex is considered to be as follows:

1. Geosynclinal sedimentary and volcanic rocks were formed and intruded by ultrabasic and basic sills, and dolerite dykes. All these rocks are part of the Halls Creek Group and considered to be Archaean in age.

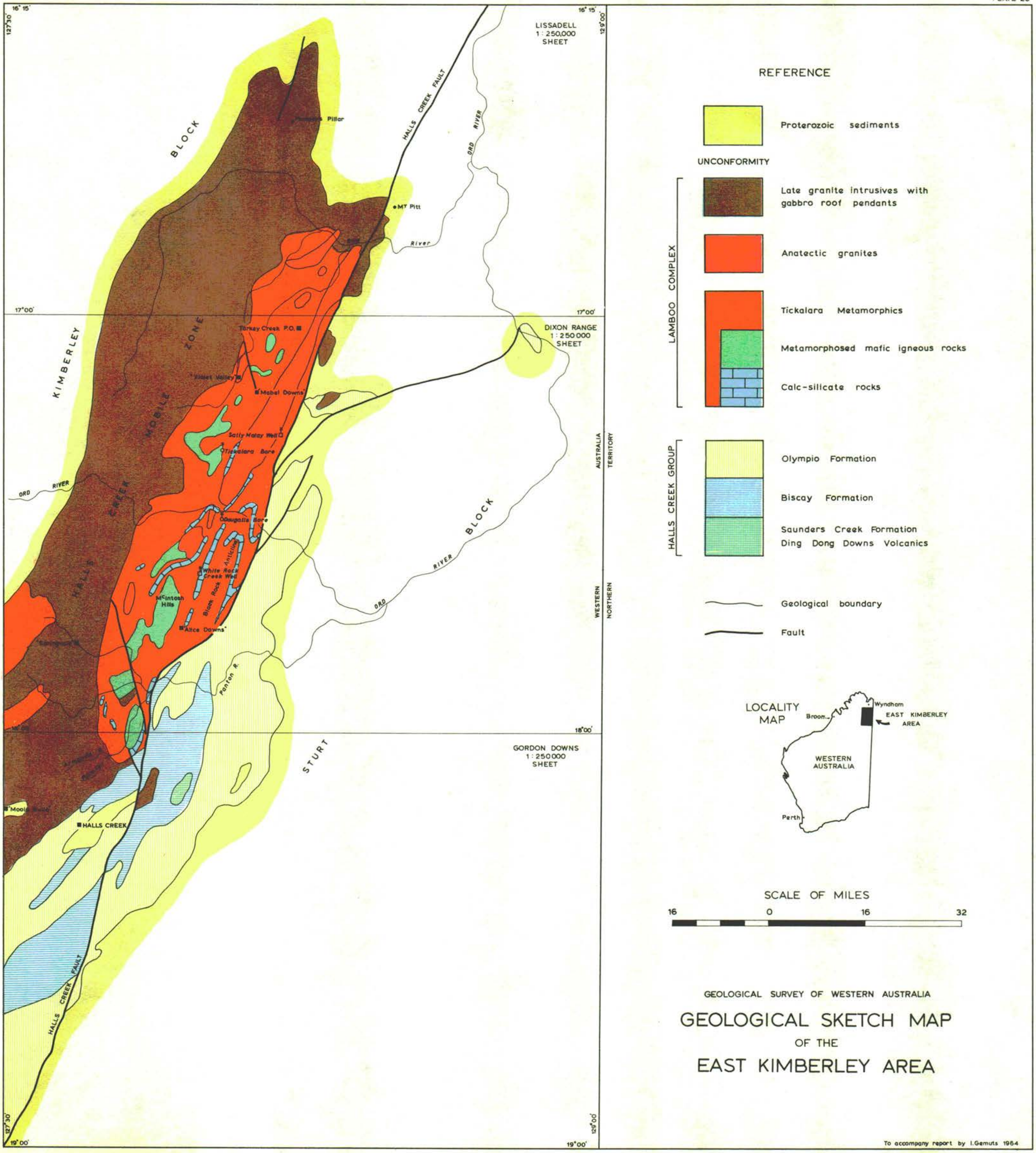
2. The geosynclinal pile was then deformed and metamorphosed. The grade of metamorphism of the rocks increased from moderate greenschist facies in the south to granulite facies in the north. The high-grade metamorphic rocks to the north, and west of the Halls Creek Fault, are the Tickalara Metamorphics. In the south the low-grade metamorphic rocks with features such as bedding, ripple marks, load casts and graded bedding are sediments of the Halls Creek Group. All the basic rocks of this group are uralitised. The metamorphism is probably Archaean in age.

Greywackes and shales of the Olympio Formation and acid volcanics of the Biscay Formation were changed to schists and gneisses of the Tickalara Metamorphics. The calc-silicates are the metamorphic equivalents of dolomites in the Biscay Formation. The amphibolites are thought to have been formed by the reconstitution of basic lava flows, basic dykes, and dolomite of the Biscay Formation. The close association of the pyroxene granulites with amphibolites indicates that many of them are higher grade equivalents of the amphibolites. Others are derived more directly from calcareous rocks and basic igneous rocks.

3. Anatectic gneissic granite was intruded during the waning stages of metamorphism, forming migmatites around the margins. Here also there was local retrogressive metamorphism. These events are probably Archean or Early Proterozoic in age.

4. Granite was intruded as a batholith along the western margin of the complex, incorporating pendants of Tickalara Metamorphics and the Halls Creek Group. The granite was intruded in Early Proterozoic time.

PLATE 20



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VERMICULITE DEPOSITS AT YOUNG RIVER, EUCLA DIVISION

by W. N. MacLeod

The vermiculite deposits at Young River, Eucla Division were discovered in 1939 by prospector G. Halbert of Ravensthorpe, and were worked by him in 1940 and 1941 for the production of 186 tons from M.C's. 204H and 205H. The deposits were taken over by the Perth Modelling Works Ltd. in 1941 and worked until 1953 with the production of 1,499.8 tons from M.C. 187H. In all 1,685.85 tons have been produced valued at £10,890; an average value of £6 9s. per ton. There has been no further development or exploration since 1953.

The deposits were first examined geologically by H. A. Ellis in 1940 and again in December, 1943. The deposits and underground workings were re-examined and mapped by W. Johnson and J. Gleeson in January, 1949. The results of these surveys are described in Annual Reports of the Geological Survey for 1943 and 1949 respectively.

The deposits were visited by the writer in April, 1964, to ascertain the state of the old workings and to review the prospecting and development programmes outlined by previous workers. Additional shafts and prospecting pits had been sunk in the period 1949-1953. (The additional information gained from these openings has been plotted on Plate 21). After a lapse of over 10 years many of the old workings had collapsed or were in such a dangerous condition as to be inaccessible. Development has been confined mostly to zones of decomposed rock of poor standing quality.

GEOLOGY OF THE DEPOSITS

Both the regional geology and geological environment of the vermiculite deposits have been described by Ellis (1943), and Johnson and Gleeson (1951).

The vermiculite occurs in irregular seams and veins in shear zones in a large ultrabasic intrusion which has been metamorphosed to an actinolite-anthophyllite-hornblende complex. This complex intrudes biotite gneiss and is in turn intruded by sills or dykes of hornblende granulite; the metamorphic derivative of a basic rock. The entire suite has been intruded by a later discordant acid granite surrounded by an aureole of minor pegmatite and quartz reefs. The vermiculite is considered to be a product of metasomatism of actinolite by fluids introduced by the late granite and the uniform relationships of these two minerals supports this view. Horses of friable green actinolite are intimately intergrown with the vermiculite along the shear zones and there is no indication that the vermiculite is due to the alteration of pre-existing micas.

The metamorphosed ultrabasic host rock of the vermiculite is very poorly exposed. The upper soil layers are heavily impregnated with magnesite. In places there has been siliceous induration of the rock with silica possibly derived from the late intrusive granite. The intrusive hornblende granulite is better exposed and its presence usually marked by lines of granulite boulders.

The ultrabasic rock has been strongly sheared with the shear directions concentrated around 320°, due north and 040°. These directions correspond in a general way to the alignment of the hornblende granulite bodies and it has been suggested that these more competent "ribs" have exerted some measure of control on the shear pattern. In underground workings individual shear zones are said to have been followed for as much as 100 feet but most of them die out both laterally and vertically over smaller distances than this.

RECOMMENDATIONS FOR PROSPECTING.

General.

Vermiculite was first discovered in this area from the acute observation of the prospector G. Halbert who noticed flakes of the mineral in the extremely large ant heaps which are typical of the area. In the absence of outcrop this is the sole indication of underlying veins of the mineral. In most openings that have been made there is seen to be a heavy development of magnesite in the upper soil profile which serves to obscure the vermiculite even directly above a wide vein. The magnesite layer is generally less than 3 feet thick but it is necessary to cut below this to gain any idea of the width or character of a vermiculite vein.

It has been suggested that the elongated bodies of hornblende granulite have exerted some measure of control on the intensity and orientation of the shear zones with which the vermiculite is commonly associated. This may be the case but it is felt that there is insufficient evidence to apply this as a general rule to the whole field as a prospecting guide for vermiculite. There is certainly a strong development of vermiculite in the northern end of the field near the boundaries of horneblende granulite but there are numerous localities, particularly in the southern end of the field, where there are occurrences of excellent vermiculite well away from such bodies. It is a possibility that more intensive shearing near the horneblende granulite has aided deeper weathering of the ultrabasic rock. As practically all development and exploration of the deposits has been deliberately confined to such easily worked zones of decomposition it is felt that this relationship could be more apparent than real and does not reflect the true character of vermiculite distribution. The prospecting of these deposits has been confined to ground that could be moved with pick and shovel and it is believed that a much more comprehensive investigation would have to be made before the relationship of the vermiculite to the hornblende granulite could be established.

Throughout the field vermiculite veins are exposed in scores of prospecting pits and shallow shafts and from the frequency of its occurrence there is the inclination to infer a very widespread distribution of the mineral. It would seem that the most efficient prospecting tool in this area would be a bulldozer capable of making a series of shallow cuts below the magnesite layer across selected areas. Only by obtaining continuous exposure of the rock below the magnesite mantle could any reliable inferences as to the persistence and correlation of the veins be made. As a prospecting tool it is not considered that the diamond drill would be of much advantage. The vermiculite veins pinch and swell and die out abruptly and pockets of workable grade could be missed entirely. Furthermore, from the character of the vermiculite flakes it is doubtful whether anything approaching satisfactory core recovery would be achieved in the zones where it would be most required. The drill would certainly be of use over short intervals in planning development ahead from existing workings, but it is not considered that it would be of much value in an overall initial assessment of the field or of selected areas of the field.

Individual Areas

In view of the collapsed state of most of the old workings any future development would have to be prefaced by a systematic exploration programme aimed at the delimitation of the richest zones of vermiculite concentration, together with an appreciation of the variations in the quality of the material. Up to the present all workings and prospecting appear to have been haphazardly based on zones of easy mining and thick veins. A continuation of such methods could lead to the rapid despoliation of a potentially valuable mineral asset.

In the present investigation an attempt has been made to select areas for systematic prospecting on the basis of evidence presented by existing openings and the information gained in past geological examinations. Four such areas have been selected, termed A, B, C and D (see Plate 21). These are dealt with as follows:

Area A is situated in the northwestern sector of the field surrounding the underground workings on No. 3 Lode. This has been the most productive zone of the field with underground workings to a depth of 60 feet. Sections of the workings are illustrated in the report by Johnson and Gleeson (1951). Since their inspection several new pits near the shaft have been sunk and some of the existing pits have been deepened. Further pits have also been opened in the area close to the granite contact, about 300 feet southwest of the shaft.

There is a large tonnage of vermiculite in the shaft dumps and it is seen in veins in all openings in the area immediately north of the shaft. The already mined material should be beneficiable, and as an immediate mining project, the area north of the shaft between the hornblende granulite and the pegmatite could be open cut.

The zone between the shaft and the pits about 300 feet southwest of the shaft would merit prospecting by a series of northeast trending cuts between the access track and the hornblende granulite intrusion. The vermiculite in the low pits near the base of the spur is of excellent quality with flakes up to 2 inches in diameter and this zone calls for closer examination.

Area B is situated southwest and south of the workings on No. 4 Lode. This lode was developed by means of a shaft and open cut. The shaft, originally 70 feet deep, has collapsed completely, as have the walls of the open cut. As at Lode 3, there is a substantial quantity of vermiculite in the dumps. South of the old workings there are numerous vermiculite veins exposed in prospecting pits and the entire area seems to hold considerable promise. Johnson and Gleeson recommended the sinking of a prospecting shaft near the northern tip of the westernmost hornblende granulite body and laid out a diamond drill programme from the base of this shaft. As most of the exposed veins have a general north strike it is suggested that a series of cuts of east trend between the road and the western granulite be made over an area measuring approximately 800 by 300 feet as outlined on the accompanying plan. The abundant quartz float and pegmatite in this zone points to a concentration of hydrothermal activity from the granite and this could favour increased concentration of vermiculite.

Area C is in the central portion of the field south of the old camp site. There are few openings in this area. A shaft 14 feet deep, has been sunk on a vermiculite seam 6 feet wide at a point about 400 feet south of the camp, and another pit has exposed a seam 4 feet wide close to the road about 350 feet southeast of the camp. The area between the track and the hornblende granulite would appear to merit prospecting as vermiculite flakes are common in the soil in many zones. If surface trenching revealed any promising concentrations in this area they could be developed by an adit from the steep cliff face along the Young River. The gully to the south of this area has been the site of shaft workings on Lode 1A and in an open cut which reached a depth of 26 feet.

Area D is in the southern section of the field and was apparently developed after Johnson and Gleeson's examination. The main openings consist of a shaft 19 feet deep and an adjacent pit 10 feet deep which have been sunk on a seam 7 feet wide of general northeast trend. Actually there are two seams exposed, separated by a narrow horse of actinolite rock. Vermiculite also appears in some nearby costeans and pits. Another pit, now partly collapsed, has been opened on a vermiculite seam about 300 feet southwest of this shaft. This opening follows the northwesterly dip of the vein which is at least 6 feet wide and strikes northeast. Vermiculite is common in the soil between the two worked areas. To the northwest there is abundant quartz and pegmatite but no exposures of the ultrabasic rock. It is recommended that this area be prospected by a series of northwest trending cuts.

CONCLUSIONS

From the data available and the mode of occurrence it is impossible to make any reliable assessment of the reserves of vermiculite available in the Young River deposits. From its widespread occurrence in thick, if impersistent seams, it is considered that the reserves could be very substantial. In view of the general decomposition of the host rock, prospecting by bulldozer cuts would appear to be the most economical and rapid means of gaining a better appreciation of the mineral distribution.

There is a very substantial tonnage of lower grade material at present lying in dumps near the old workings. Any further development of the deposits should include consideration of the beneficiation of this material. In past working the vermiculite has been mined selectively to produce a usable product and in consequence a great quantity of contaminated material has been rejected into dumps. There is probably more vermiculite lying in these dumps than has been taken away.

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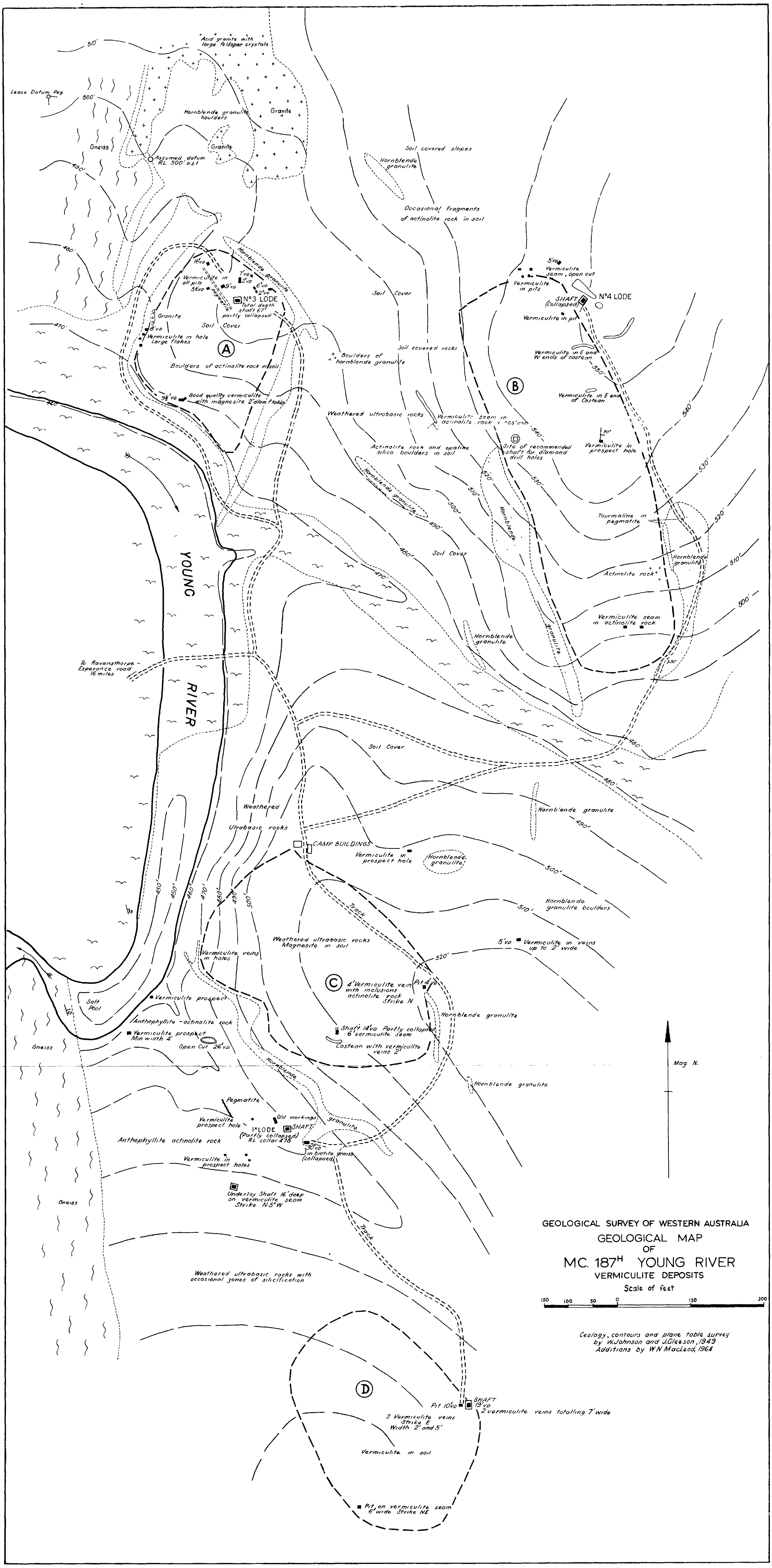

PLATE 21

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THE NARLARLA LEAD - ZINC DEPOSITS, BARKER RIVER AREA, WEST KIMBERLEY GOLDFIELD

by R. Halligan

ABSTRACT

The Narlarla lead-zinc deposits are near Napier Downs Station, about 85 miles by road east of Derby, West Kimberley Goldfield. They consist of two deposits, known as No. 1 and No. 2; No. 1 has been mined out and No. 2 is being worked at present by Devonian Pty. Ltd. The deposits have been known since 1906, and have been worked intermittently since then. To date, about 9,000 tons of ore have been won, averaging over 40% total lead plus zinc. At present the body is worked in a small open cut and the ore is shipped from Derby to Europe for smelting.

The ore bodies have been largely controlled by faulting. They lie within the Napier Limestone, a Devonian fore-reef facies deposit which unconformably overlies granite, gneiss and schist of the Precambrian Lamboo Complex.

The No. 2 ore body is a massive, finely crystalline lead-zinc sulphide deposit which is rather irregular in form, overlain by a mass of secondary oxide and carbonate ore. Silver is also present. The secondary minerals form a cap to the main sulphide body, but they are also present in fault zones as "shoots" or apophyses which are separated by "ridges" of unaltered limestone.

Total indicated reserves of high grade ore are 11,500 tons, of which about 7,750 tons has already been mined.

The galena is abnormally rich in radiogenic lead, which suggests that the genesis of the ore is due to remobilisation of older lead-zinc from a vein in the Lamboo Complex, with subsequent re-deposition in a faulted area of Napier Limestone. Alternatively, the abnormal lead isotope ratios could be due to contamination of the mineralising fluids by radiogenic lead contained in the basement rocks themselves.

No other deposits of this nature are known in the State and this is the youngest dated ore body in Western Australia. Exploratory drilling, geochemistry, and geophysics are suggested as possible means of discovering further ore.

INTRODUCTION

The Narlarla deposits are located in the Napier Range on the south side of the Barker River Gorge, about 2 miles by road from Napier Downs Homestead and 85 miles east by good road from Derby (see Plate 22). The location is marked on the map of Finucane and Jones (1939) and on the Lennard River 4-mile geological map produced by the Bureau of Mineral Resources, Canberra (1956), where it is shown as "Devonian Lead Mine".

The deposits were originally pegged by R. B. Pettigrew and F. Wilson in 1901, but were later abandoned. In 1906 they were taken up by Mr. G. J. Poulton, a former owner of Mondooma Station, West Kimberleys, and investigated by a Mr. J. H. Grant. According to a newspaper report of June 8th, 1906, Grant estimated the ore in outcrops at "over 5,000 tons" and a shaft and crosscut were put in. A company was floated to mine these ores, and apparently there was considerable speculation in the shares at that time. As a result, the find was investigated by Mr. W. Windred, a Tasmanian prospector who thought the place "over-estimated", and also by H. P. Woodward, the then Assistant Government Geologist. Woodward (1906) described the two ore bodies, but suggested that it was probably not an economic proposition because of the high cost of cartage. He advised intending prospectors to wait till further work had beeen done on the deposits, whereupon the venture seems to have collapsed. A short report with some assays, presumably of samples collected by Woodward, was later made by Simpson (1951).

Finucane and Jones (1939) re-examined the deposits during the Aerial, Geological and Geophysical Survey of Northern Australia, and Prider (1941) has reported on the mineralogy.

The deposits have been worked intermittently from 1948 onwards. The ore bodies have little surface expression at the present time, but prominent outcrops of secondary ore, which have since been mined, led to their original discovery. Early work was almost entirely in the secondary ore, though sulphides were known from the crosscut (Woodward, 1906; Finucane and Jones, 1939). Since 1947, Mr. E. Russell and his partners in Devonian Pty. Ltd., have held the mine. In 1952, the deposits were drilled under option by Zinc Corporation, but no development work was undertaken. In 1964 Devonian Pty. Ltd. opened up the present workings, to take advantage of the Imperial Smelting Process for mixed lead-zinc ores which, together with the present high prices for lead-zinc, makes these workings a commercial proposition.

GEOLOGY

Host Rock

The ore bodies lie within fore-reef facies limestone (calcarenite and calcirudite) of the Upper Devonian Napier Limestone. Interbedded thin green siltstone is also seen in some exposures. The rocks dip generally at 20° to 30° to the west and southwest, forming a gentle anticline which plunges west-southwest at a low angle. The Napier Limestone overlies Precambrian gneiss, schist, and granite of the Lamboo Complex.

The Ore Bodies

There are two deposits, No. 1 and No. 2.

No. 1 ore body has been almost completely worked out. It consisted of a low hill of cerussite and hydrozincite, with some galena, blende, limonite, and minor malachite and chessylite (azurite). Some loose fragments at the surface contained up to 40% hydrozincite (Prider, 1941). Workings consist of an east-west trench 60 feet long and 15 feet wide, with a shallow pit at the western end. Slickensides, together with a sharp change in strike in a green silty shale exposed in the floor of the trench suggest that a fault may have provided a focus for the ore. The limestone dips at about 20° to the west.

No. 2 ore body lies 1,600 feet southwest of No. 1, on the southeastern limb of the anticline, and is exposed in an open pit about 60 feet square and up to 40 feet deep, with an inclined entryway on the southeastern side. It consists of a massive sulphide body overlain by an irregular mass of secondary ore. The distribution of ore is largely controlled by faults (see Plate 22).

The sulphide body consists of fine-grained crystalline galena (crystals generally less than ⅛-inch face) with some interstitial powdery black sulphide. Pyrite and chalcopyrite are sometimes present, though generally in minor amounts, and from the presence of zinc in analyses, zinc blende must also be present. At the time of inspection, about 10 feet of sulphide ore was exposed on two sides of the open cut, and exploratory drilling has proved this ore to depths of from 4 to at least 16 feet below the floor of the cut. Immediately overlying the sulphides is a narrow zone of a bright red powdery or clayey rock, averaging 2 feet thick, often associated with a green clay. This zone coincides with the water level reached in the old workings. The red zone contains from 39% to 44% zinc, and probably consists largely of zincite; some lead and silver minerals are also present. Other secondary minerals, mainly cerussite, with some malachite, azurite, hydrozincite, calcite, and limonite occur above the red zone. Galena is also present in minor amounts. The secondary ore is soft, porous, and mottled pale brown and white in colour, with a definite "sparkle" in some outcrops; some vuggy material occurs in this zone, along the line of one of the faults; calcite, cerussite, and limonite are commonly developed within the vugs as crystals, stalactitic growths, and encrustations.

Secondary minerals have developed in fault zones appreciably higher than in the areas between such zones. Thus it was found that working the secondary zone was complicated by "ridges" of limestone within the secondary ore body. It seems that the ore worked in the early days was located on a fault or faults on the northeastern margin of the present workings. The throw of such faults as can be measured is less than 5 feet, but in most cases no estimate can be made. Slickensides are developed on the fault planes in the limestone and in several cases a black or grey sulphide-rich pug is developed at the fault plane. This pug probably represents fault gouge material, and indicates some fault movement after the deposition of the ore. It is interesting to note that the supergene ore is generally high in zinc and low in lead, while lead is relatively more abundant in the sulphide body.

The sulphide body, as shown by drilling, gives a roughly rhomboidal outline when projected at the surface and has abrupt margins. The southwestern face of the cutting, which is parallel to the strike of the Napier Limestone, shows some exposures of the contact with country rock which suggest a conformable upper limit to the body, but this is probably due to coincidence of the water table with the trace of the bedding in the face. Other exposures, e.g. on the northeastern and northwestern faces, show that faulting defines the lateral extent of the mineralisation. The base of the ore body has not been exposed to any extent, but three exploratory holes drilled from the flat floor of the open cut show that it is likely to be influenced by faulting, and therefore irregular. The bottom sulphide-limestone contact was met at depths of 4 feet and 7 feet, in two holes, but the third hole was still in ore at 16 feet; the contact at 4 feet was on strike with a limestone "ridge" previously encountered during mining of the secondary zone. As previously explained, such ridges represent unaltered limestone between mineralised fault zones. The small ore sections encountered in drillholes 1, 9 and 12, away from the main ore body, probably represent mineralisation on other faults.

Ore Genesis

Several modes of origin of the Narlarla lead have been considered. Finucane and Jones (1939) state that "In their general mode of occurrence and mineral constituents they are similar to the lead ores of Missouri, except that they contain a little more silver. There is no evidence of post-Devonian igneous activity in the area and it is probable that the ores were formed by deposition from waters of meteoric origin." Thus they envisage a syngenetic origin for the lead and zinc. However, post-Devonian igneous rocks, occurring as small volcanic necks and plugs, are known from Mt. North, Mt. Percy, and further to the south in the northern part of the Canning Basin.

Prider (1941) has suggested that there might be a connection between this igneous activity and the sulphide mineralisation. Mt. North lies 17½ miles to the south-southeast of Narlarla. No trace of igneous rocks has yet been seen in or near the mine.

A third hypothesis now proposed suggests that the ore was derived directly from lead mineralisation in the underlying Lamboo Complex. The cause of the remobilisation is not known, but in the absence of nearby igneous activity, it probably was due to migrating ground water. Lead veins are known to occur in these rocks in other parts of the Kimberleys, e.g. Mt. Amherst, Argyle Downs, Alice Downs, Pandanus Creek, Old Leopold Downs; in addition, lead minerals, probably associated with gold, have been reported from several places in the East Kimberley District and from Barker River and Richenda River in the West Kimberley. The Old Leopold Downs locality is about 90 miles southeast of Narlarla.

A. F. Trendall (pers. comm.) drew attention to the fact that a lead isotope determination had been made on lead from Narlarla (Farquhar and Cumming, quoted in Russel and Allen, 1957), and suggested that an age determination might help fix the date of formation or concentration of the ore. R. M. Farquhar, who made the Narlarla determination, was asked to comment on his results; he states in a letter that the Narlarla sample "contains more radiogenic Pb^{206}, Pb^{207}, Pb^{208}, than average Tertiary or Recent leads, and I think this pretty certainly means that the sample has been enriched by lead extracted from granitic basement rocks". Farquhar also drew attention to recent lead isotope work done on lead ores by Slawson and Austin (1962), who describe lead mineralisation in limestones in New Mexico. They postulate that mineralising fluids formed deposits in two zones. The first, above a zone of crustal weakness, yields "modern" lead isotope ratios. The second, away from the zone of weakness, yields anomalously high lead isotope ratios, and this they attribute to contamination of the mineralising fluids as they passed through basement rocks containing radiogenic lead. In one case however, they suspect contamination from an older mineral deposit. On the other hand, Eckelmann and Kulp (1959), and Eckelmann and others (in press), describe anomalous lead ratios from deposits *close to the ore channels*. Thus they envisage an anomalous lead isotope ratio present in the original mineralising fluids, and while they suggest that this is produced by "inhomogeneous extraction of lead from granitic rocks in the basement" it could, presumably, be due to extraction from a pre-existing ancient lead deposit.

Applying these hypotheses to the Narlarla bodies, it seems that they are most likely due to remobilisation of pre-existing mineralisation in the Lamboo Complex; ore search for similar bodies should thus be aimed at finding suitable structures in the Napier Limestone close to or overlying lead veins in the Lamboo Complex (see Eckelmann and Kulp, 1959). On the other hand, there is the possibility that the deposits could be due to mineralising fluids derived elsewhere, possibly at some distance from the host rocks (see Slawson and Austin, 1962; Prider, 1941). This would greatly widen the target area for ore search.

ORE RESERVES

The true shape of the No. 2 ore body is not known, so ore reserve estimates are necessarily approximate.

From available data, it is calculated that the mean cross section area of oxidised ore is 825 square feet, which at 10 cubic feet per ton over 60 feet mean length amounts to 4,950, say 5,000 tons. Similarly, there is indicated 907.5 square feet of sulphide ore, over a mean length of 50 feet. Using a factor of 7 cubic feet per ton, sulphide ore reserves are 6,482, say 6,500 tons. Total indicated reserves of high grade ore are thus 11,500 tons, of which about 7,750 tons has already been mined and shipped to the smelter, leaving 3,750 tons as indicated reserves.

In addition, a quantity of concentrates from earlier workings are available at grass. No new ore reserves have been discovered within the lease during the current production period.

GRADE

Drill logs and assays and channel sample assays by Zinc Corporation are given in Halligan (1964). The sulphide ore is of good grade, containing between 27% and 68% lead plus zinc over ore sections which range between 7 and 37 feet in thickness. The silver content varies between 0 and 6.2 fine oz. per ton. The secondary ore shows values ranging from 2.8% to 32.4% lead, 3.8% to 32% zinc, and 0 to 8.6 fine oz. per ton silver. No systematic sampling of ore has been done during mining, but grab samples from mined ore are taken from time to time.

PRODUCTION

Mines Department statistics show that from July 1948 to June 1964 ore mined was 1,844.14 tons, yielding concentrates containing:

	Value £
Lead 731 tons (f.o.b. Fremantle)	42,289.
Zinc 342.31 tons (f.o.b. Fremantle)	1,376.27
Silver 13,630.87 fine oz.	3,069.23
Total	46,733.60


CROSS-SECTION A-A'
CROSS-SECTION B-B'
Profile of secondary ore (after Zinc Corp. 1952)
Fault (after Zinc Corp.1952)
Limestone 'ridge' (driller's report)
Intermittent traces of Pb,Zn (0·01-0·71)
Intermittent traces of Pb,Zn (0·1-0·6%)
1" Sulphide
12" Sulphide
TD71'
TD87'
TD125'
TD206'
Depth indicated by Wagondrilling in pit
MN
Secondary ore (After Zinc Corp.)
Position of old buildings (Since destroyed)
Broken and disturbed limestone
Old skip rail cutting
Slickensides
Slickensides and broken Rock
Floor of open cut
Top of open cut
Section A Line
Section B Line
Kimberley Division
Wyndham
Narlarla
Derby
Old Leopold Downs
Mt Amherst
Halls Creek
0 miles 100
REFERENCE
Mined out / In situ } SECONDARY ORE
Mined out / In situ } HIGH GRADE SULPHIDE ORE
Dn DEVONIAN NAPIER FORMATION
GEOLOGICAL BOUNDARY (Position approximate)
FAULT
ANTICLINE SHOWING PLUNGE (Position approximate)
LIMIT OF OPEN CUT (Plane table survey, J. Jeppe. 1964)
O3(Vert) DRILL HOLE (Zinc Corp. 1952)
FORMER SHAFT (Now mined out)
GEOLOGICAL SURVEY OF WESTERN AUSTRALIA
PLAN AND SECTIONS
OF
THE NARLARLA LEAD-ZINC MINE No2 ORE BODY
WEST KIMBERLEY G.F.
Scale
20 10 0 20 40 60 feet
R. Halligan. 1964

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Mr. E. Russell states that about 600 tons of ore was won from the No. 1 body. Since then, in August 1964, 3,750 tons of ore was shipped overseas from Derby, and a further 4,000 tons was shipped in October 1964. Assay figures and values are not yet available for these shipments.

METHOD OF WORKING

Open cut mining is used. Overburden and ore are worked by blasting, then removing the rill with a mechanical shovel and tip truck. A tractor-mounted Holman drill is used to drill shot-holes, and also for exploratory drilling. The ore is sent by road to Derby, and shipped from there to Europe for smelting. Water in the workings is not a problem so far, and a small portable pump is used to dry out the floor of the cut each day.

RECOMMENDATIONS

1. Because of the irregular nature of the body, all mining should be preceded by test holes drilled from the working face in the proposed direction of mining.

2. Test holes should be drilled west of the present workings to seek any possible extension controlled by the fold and fault directions detected in the area.

3. Test holes should be put down on the north-east side of the present workings. No holes have been drilled here as yet, but it is known that galena was struck when the foundations were dug for the old mill building. It is also possible that ore could be repeated on this side by faulting.

4. An inclined test hole should be drilled from south of No. 1 body in a northerly direction, to search for possible sulphide mineralisation beneath the secondary ore.

5. Geochemical and geophysical prospecting of the Napier Limestone and of other Devonian limestones might be carried out to locate further bodies. Geochemical stream sampling would be the quickest prospecting method, as the limestones are very difficult to traverse, due to their karst-type weathering. Geophysics would be necessary to locate any bodies as yet uncovered; electromagnetic and induced polarisation would probably be the most reliable methods here. Faulted areas of limestone would seem to be the most likely areas of mineralisation.

ACKNOWLEDGMENTS

I would like to thank Mr. E. Russell and his partners of Devonian Pty. Ltd., for their help and hospitality when working at the mine, and Dr. J. F. B. Jeppe of the University of Western Australia, for much helpful discussion and for the use of his maps and other information.

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INVESTIGATION OF MANGANESE DEPOSITS IN THE MT. SYDNEY—WOODIE WOODIE AREA, PILBARA GOLDFIELD

by L. E. de la Hunty

ABSTRACT

Diamond drilling of manganese deposits at Mt. Sydney and Woodie Woodie was undertaken in 1964, as a joint venture by the Department of National Development and the Western Australian Mines Department, to provide additional information on the mode of occurrence of the deposits. Gravity surveys were also carried out and a geological survey was made of a restricted area. Information was also gained from recent mining activity.

The area is the main source of high-grade metallurgical manganese ore in Australia with an average annual production of about 30,000 tons for the past 5 years. Most of the production has been from Mineral Claim 269 at Woodie Woodie; other deposits are worked intermittently.

The manganese deposits are supergene cavity fillings in the Carawine Dolomite (Lower Proterozoic), probably emplaced during the Upper Proterozoic Era. The deposits are associated with the Pinjian Chert Breccia and are probably of comparable age. They are older than the Waltha Woora Beds, which are Upper Proterozoic, and have been acted upon by Permian glaciation and Cainozoic weathering processes.

Three holes were drilled, one at Mt. Sydney and two at M.C. 268, Woodie Woodie. The drill-hole at Mt. Sydney indicated little depth extension beyond the quarry floor of the ore body on M.C. 532. However, an intersection of high-grade ore was made in D.D.H. No. 1, on M.C. 268, at a vertical depth of 75 feet; and the attitude grade and extent of that ore body was indicated. A concealed ore body was also intersected and this is considered worthy of further testing by vertical wagon drilling.

Drilling, gravity testing and mining development during 1964 have increased the indicated reserves of manganese ore in this area.

INTRODUCTION

Early in 1964 the Commonwealth Department of National Development financed a programme of diamond drilling designed to provide additional information on the mode of occurrence and origin of manganese deposits in the Mt. Sydney and Woodie Woodie areas of the Pilbara Goldfield. The drilling was carried out by a Mines Department crew, and the programme was planned and supervised by the writer.

D. L. Rowston of the Geological Survey, carried out gravity surveys on selected ore bodies in the area in May and June, 1964, and the writer remapped the area.

Additional information was gained from the new openings made by the mining companies during 1964, on M.C.s 269 and 487.

GENERAL INFORMATION

LOCATION

Both the Mt. Sydney and Woodie Woodie areas lie within Warrawagine Cattle Station in the East Pilbara District. Mt. Sydney is 186 air miles east-southeast of Port Hedland and the distance by graded road is about 230 miles. The Woodie Woodie area extends from about 10 to 30 miles south of Mt. Sydney.

PRODUCTION

Manganese ore was first shipped from this area in 1954 and production has been continuous since then. Total production to the end of September, 1964 was about 231,000 tons. The grade of most of the ore produced was greater than 50% Mn.

MANGANESE PRODUCTION*

Year	M.C. 532	M.C. 268	M.C. 269	Other Claims
	Tons	Tons	Tons	Tons
1954	....	....	6,000	6,000
1955	....	12,200	....	....
1956	....	....	....	....
1957	....	13,500	....	....
1958	10,000	4,000	2,800	800
1959	....	....	19,300	....
1960	....	....	29,400	....
1961	....	....	32,400	....
1962	....	....	38,400	....
1963	....	....	22,500	....
1964†	....	....	29,800	3,900
Total	10,000	29,700	181,500	10,700

* All tonnages are approximate.

† Figures quoted for 1964 are to the end of September only.

GEOLOGY

The manganese deposits in this area are all associated with Proterozoic rocks; more specifically with the Carawine Dolomite and younger rocks. In other localities (e.g. Ripon Hills, Skull Springs, Mt. Cooke) the manganese deposits have been formed by supergene enrichment of manganiferous sediments (de la Hunty, 1963), and mining has revealed that they have little depth extension. However, the deposits at Mt. Sydney and Woodie Woodie form cavity fillings and replacement deposits in dolomite, and are known to extend to more than 100 feet depth (M.C.269), although still supergene at that depth. The ore was deposited from solution in circulating waters.

The deposits are generally associated with outcrops of the Waltha Woora Beds, but have not been derived from them. The Waltha Woora Beds are demonstrably younger. Locally, the Waltha Woora Beds appear to be conformable with the Carawine Dolomite, but there is actually a large time interval between the deposition of the two units.

Manganese is known to be mobile under present weathering conditions but the main period of manganese emplacement was obviously subsequent to the exposure of the Carawine Dolomite and prior to the deposition of the Waltha Woora Beds.

STRATIGRAPHY

The oldest rocks exposed in the area mapped are of Lower Proterozoic age. These are unconformably overlain by rocks of the Upper Proterozoic, Permian glacials and Cainozoic sediments (Plate 23).

Lower Proterozoic

The *Little De Grey Lava* is the oldest rock mapped. It is an amygdaloidal basalt with abundant interbedded coarse pyroclastics; it contains the Tumbiana Pisolite Member, which was mapped near the Ragged Hills Lead Mine and also in the southeastern part of the area. This basalt has been correlated with the Mt. Jope Volcanics (MacLeod and de la Hunty, in press). It is folded and sheared and has been intruded by mineralised quartz reefs containing galena, sphalerite and pyrite. To the east of the area mapped, the basalt is intruded by Proterozoic granite (Noldart and Wyatt, 1962). No mineralisation was seen in the basalt in the western part of the area.

The Lewin Shale was first reported by de la Hunty (1963) and was subsequently correlated (MacLeod and de la Hunty, in press) with the Jeerinah Formation and the Marra Mamba Iron Formation. It lies conformably between the Little De Grey Lava and the Carawine Dolomite and consists of shale, chert, jaspilite and thin-bedded dolomite. The average thickness is 400 feet.

The *Carawine Dolomite* has been correlated with the Wittenoom Dolomite (MacLeod and de la Hunty, in press) and is therefore assigned to the Lower Proterozoic. The Wittenoom Dolomite is known to be older than 2,100 million years from radiometric dating of younger rocks. The Carawine Dolomite is the host rock for the manganese deposits on the eastern limb of the Oakover Syncline. It is a blocky, grey and pink, crystalline, dolomitic limestone with chert bands, and contains *Collenia* in its lower part. In many localities, the upper part of this formation is thin-bedded and contains many bands of chert. This is the source of the material for the Pinjian Chert Breccia. The dolomite is also partly silicified but this has probably resulted from weathering. The thickness of the Carawine Dolomite is about 500 feet in this area.

Upper Proterozoic

The Upper Proterozoic *Pinjian Chert Breccia* is about 100 feet thick. It was formed by the cementing, with silica, of angular fragments of chert which have been derived from the Carawine Dolomite. These fragments are characteristically angular but some are partly rounded. Some of the breccia was formed by faulting but most of the chert fragments were caused by the collapse of chert bands when the intervening dolomite had been dissolved out during weathering. The fragments were then cemented together in situ or transported and then cemented. The Pinjian Chert Breccia is not confined to any level. It is generally present on accordant hilltops but is also exposed at plain level 2½ miles northeast of Carawine Gorge. There does not seem to be a local base level of weathering relative to the plateau level. The relative depth of weathering varies by as much as 200 feet over a distance of half a mile, as in the dolomite southwest of Mt. Sydney.

The Pinjian Chert Breccia contains a grooved, striated, glacial pavement at plain level near Carawine Gorge, another at Woodie Woodie, and one in the Ripon Hills (west of the area); so in these localities the unit is older than Permian. However, chert breccia of Tertiary age is also known south of the area (de la Hunty, 1963), so it is probable that not all of the chert breccia in this area is pre-Permian.

The *Waltha Woora Beds* were named by Noldart and Wyatt (1962). They are thin-bedded, pink, calcareous siltstones, fossiliferous, pink, siliceous dolomite, thin-bedded grey dolomite, shale and sandstone. The thickness of the beds exceeds 500 feet. Within the area investigated, these rocks are restricted to the eastern part of the Oakover Syncline. Some superficial manganese staining was observed on sandstone near M.C. 274, but the Waltha Woora Beds are characteristically barren of manganese oxides.

In many places the basal bed is a pebbly sandstone that locally is more than 150 feet thick. It is best developed in the Woodie Woodie locality and is correlated with the long outcrop of pebble conglomerate on the fringe of the desert about 10 miles east. This is called the Googhenama Conglomerate and is younger than the Upper Proterozoic manganiferous sediments to the south (de la Hunty, 1963).

H. S. Edgell, of the Geological Survey, identified *Collenia undosa* in a specimen of the pink siliceous dolomite which was deposited in "littoral to intertidal conditions." The rock has a cuspate surface and the cusps are constant (about 1 cm across) throughout the rock, which is about 20 feet thick.

Permian

The *Braeside Tillite* has been described previously. It is demonstrably younger than the Waltha Woora Beds, since it contains erratics of pink siltstone, and it has been correlated with Permian glacial deposits elsewhere in Western Australia. It also contains boulders of manganese ore and overlies manganese deposits. Steep to overturned dips in thin-bedded glacial beds were exposed by bulldozing along the eastern edge of the ore body on M.C. 487.

Cainozoic

The western side of the Oakover Syncline, in the vicinity of Carawine Gorge, is the type area for the *Oakover Formation.* It consists of white limestone and river gravel with an opaline cap, with a layer of soil with iron pebbles at the base. In many places the limestone surrounds glacial boulders, so that the boundary between the Oakover Formation and the Braeside Tillite is indistinct. The Oakover Formation probably covered all of the glacials in the Oakover Syncline but much of the cover has since been stripped—leaving plateaux and mesas about 100 feet high.

Other Cainozoic sediments in the area are colluvium and alluvium.

Intrusives

The only intrusive rock in the mapped area is dolerite which intrudes the Carawine Dolomite near Mt. Sydney and Carawine Pool. There are two dykes at Mt. Sydney, and it appears from photo-interpretation that the more northerly of these intrudes the Waltha Woora Beds; but this has not been established.

STRUCTURE

The Oakover Syncline is the dominant structural feature of the area. It trends generally 330° but is nearly north in the southern part of the area. It has a low northerly plunge and is more than 20 miles across. The folding took place subsequent to the deposition of the Upper Proterozoic rocks but before the Permian glaciation.

In the vicinity of the deposits, minor folds are generally parallel with the axis of the main syncline, and the en echelon nature of the folding is evident from the outcrop distribution of the Waltha Woora Beds. Two exceptions are the fold trending 285° at Mt. Sydney, and that trending 300° 3 miles east of M.C. 268.

Although the folding is generally simple and of low amplitude, the beds are overturned 4 miles northwest of Mt. Sydney, and isoclinally folded a further 2 miles to the northwest.

Faulting is in the direction 285° at Mt. Sydney and in the southeastern part of the area; also at 320° just south of Ragged Hills Mine, east of M.C. 268, and in the southwestern part of the area. Another fault direction at 015° was observed at Mt. Sydney.

GEOPHYSICAL WORK

Rowston (1965) carried out gravity surveys over several manganese deposits in the area, to test the efficiency of the gravimeter in determining the presence of concealed manganese ore. He concluded that the method was "a rapid and relatively inexpensive way of examining a prospect" and that it could be useful in testing for a concealed deposit.

He estimated a tonnage of just less than 700,000 tons for the ore body on M.C. 487, and subsequent mining of this deposit is tending to confirm his estimate. Satisfactory results were also achieved in gravity work over the western ore body on M.C. 269.

DIAMOND DRILLING

The diamond drilling programme was designed to give information on the attitude and composition in depth of the ore bodies in this area. The total footage drilled was 576 feet—250 feet on M.C. 532 at Mt. Sydney, and 326 feet on M.C. 268 at Woodie Woodie. The programme was modified considerably during its progress: modifications were occasioned by the high cost of drilling relative to the amount of money available for the work, and by the knowledge gained from holes drilled.

Inclined holes were favoured since, as can be seen at M.C. 268, they offer the greatest chance of making an intersection when the attitude of the orebody is unknown. Once the attitude of the orebody is established, a wagon drilling programme, using vertical holes, is desirable.

The surface rock on M.C. 268 is chert breccia and thin-bedded chert; both varieties of chert are hard and highly jointed. Several diamond bits were wrecked in this material and drilling costs were high. However, it was thought inadvisable to resort to wagon drilling in this broken ground because of the danger of jamming the bit. Small pieces of chert could fall into the hole behind the bit, causing the loss of the bit and the hole.

Core recovery was good in the ore bodies but low in country rock.

M.C. 523—MT. SYDNEY

Two holes were planned to test the ore body at Mt. Sydney, but drilling was terminated after only one hole, for financial reasons.

There was a small intersection of high-grade ore at 128 feet in D.D.H. No. 1—probably a "root" from the main ore body—but there was little indication of an economic ore body in depth. The targets for this hole were the vertical, or near-vertical, depth extension of the ore body and possible extensions along the contact between the blocky, thick-bedded Carawine Dolomite and the underlying thin-bedded, shaly dolomite (Lewin Shale).

D.D.H. No. 1

D.D.H. No. 1 was drilled to 250 feet—90 feet past the last small intersection of manganese ore (Plate 24). The main features of the hole were:

1. the presence of dolomite throughout the hole.
2. the absence of an ore body.
3. the low core recovery.

1. The hole was in finely-brecciated, pink, crystalline dolomite throughout. The only variations throughout the core were a few small seams of manganese oxide and earthy calcite. The core following the 7-foot cavity at 225 feet was probably Lewin Shale but it differed little from the previous core.

2. Small deposits of manganese oxide were intersected at 96 feet (5 ins.), 128 feet (29 ins.), about 147 feet (4 ins.), and about 159 feet (9 ins.). The largest two are probably depth extensions of the main ore body, in a cavernous zone, but are too small to be economic. The ore at 128 feet assayed 56.6% Mn, 1.80% Fe, and 4.92% SiO_2.

3. Although the core recovery in the manganese oxide was 100%, the overall core recovery for this hole was only 25%. This is due, no doubt, to the highly cavernous nature of the dolomite in this locality.

M.C. 268—WOODIE WOODIE

Two holes were drilled on M.C. 268—each with azimuth 279° and angle of depression of 45° (Plate 25). The first hole was designed to intersect the ore at less than 200 feet in the drillhole—assuming a steep easterly dip for the orebody. The intersections made with the hanging wall and footwall revealed the dip of each wall, and indicated a lensing and flattening of the ore body, down-dip to the east. D.D.H. No. 1 intersected the main ore body at 112-142 feet in the hole, but the ore intersected at 43 feet and 54 feet in the second hole is not part of the main orebody, nor does it crop out. The small intersection of manganese ore at 134 feet in D.D.H. No. 2 is probably the eastern extention of the main ore body.

D.D.H. No. 1

D.D.H. No. 1 was drilled to 171 feet—29 feet past the footwall of the ore body. Core recovery was 78 per cent. in the ore and 65 per cent. overall. The main features of the hole were:

1. a hard silicified hanging-wall rock.
2. a high grade ore body, 30 feet thick.
3. a soft dolomite footwall rock.
4. cavities at both hanging-wall and footwall.
5. the presence of the mineral chalcophanite.
6. the distribution of hematite.

1. The hanging-wall rock was jointed chert breccia and thin-bedded chert, with joint fillings of manganese dioxide, chalcophanite and hematite. It contains minor amounts of jasper and several narrow, non-coring zones. The rock has resulted from the jointing, brecciation, oxidation, and almost complete silicification of a rock consisting of alternating thin layers of chert and dolomite. The rock is part of the Carawine Dolomite.

2. The high-grade ore intersected in the drill-hole is the depth extension of the body mined in the open-cut. Assays of samples taken over 5-foot lengths (see Table 1) indicate that the intersected ore contains more than 50% Mn, less than 2% Fe, and less than 13% SiO_2. Mineral determinations made at 4-foot intervals on this ore (see Table 2) indicate that replacement by cryptomelane has taken place at the hanging wall of an ore body, which was originally emplaced as braunite, chalcophanite, pyrolusite and quartz. Replacement is almost complete at 113 feet but has not penetrated far beyond 121 feet. Dolomite was the only other mineral determined in these samples, although barite was seen at about 120 feet in the core.

3. The footwall rock is pink crystalline dolomite, with minor manganese staining and some thin bands of hematite. The dolomite is thick-bedded and easily drilled. It underlies the ore body at the open-cut.

4. The presence of cavities at the hanging-wall (4 feet) and footwall (3 feet) supports the idea of emplacement of the manganese deposit by deposition from solution in a cavity in dolomite. The ore is porous and the pores are probably cavities from which calcite (?) has been dissolved.

5. The mineral chalcophanite has not been identified from any other ore body in this area, and the determination is somewhat suspect in this instance as the mineral contains little more than a trace of zinc. However, it has the optical and X-ray properties of chalcophanite. It is finely disseminated throughout the ore, except at the hanging wall. There are also some small black crystals in places in the hanging wall rock which have a bronze sheen and may be chalcophanite.

6. There are several seams of earthy hematite in both the hanging-wall and footwall rocks of the ore body, but there are no hematite seams in the ore. Nor is there much hematite in the ore, the maximum Fe content being 3.07%. The low hematite content is a feature common to most of the deposits in dolomite in this area. Many of these deposits have a hematite "shell" which indicates the outer limits of the ore body. This shell is usually only a few inches thick but is often very high grade, fibrous, platy hematite.

Table 1

SAMPLING DETAILS—WOODIE WOODIE

Sample No.	Locality of Sample	Assay Results		
		Mn	Fe	SiO_2
2993	D.D.H. No. 1 : 112′ 0″ to 117′ 0″	50·5	1·83	11·7
2994	,, ,, 117′ 0″ to 122′ 0″	53·2	1·40	8·05
2995	,, ,, 122′ 0″ to 127′ 0″	52·7	1·28	13·8
2996	,, ,, 127′ 0″ to 132′ 0″	48·4	3·07	16·2
2997	,, ,, 132′ 0″ to 137′ 0″	50·7	1·24	18·9
2998	,, ,, 137′ 0″ to 141′ 9″	53·8	2·03	7·22
10344	D.D.H. No. 2 : 42′ 9″ to 48′ 0″	51·9	1·38	15·7
10345	,, ,, 54′ 1″ to 58′ 0″	47·1	1·37	26·2
10346	,, ,, 58′ 0″ to 61′ 7″	54·3	1·19	15·3

Note.—All samples are of split core.

Table 2

MINERAL DETERMINATIONS—WOODIE WOODIE

Sample No.	Locality of Sample	Determination
2985	D.D.H. No. 1, 113 feet	Cryptomelane, a little braunite and quartz.
2986	,, ,, 117 feet	Braunite, chalcophanite, cryptomelane and quartz.
2987	,, ,, 121 feet	Braunite, dolomite, chalcophanite, cryptomelane and quartz.
2988	,, ,, 125 feet	Braunite, chalcophanite, pyrolusite and quartz.
2989	,, ,, 129 feet	Braunite, chalcophanite, pyrolusite and quartz.
2990	,, ,, 133 feet	Braunite, chalcophanite, pyrolusite and quartz.
2991	,, ,, 137 feet	Braunite, chalcophanite, pyrolusite and quartz.
10347	D.D.H. No. 2, 44 feet	Braunite, pyrolusite, a little cryptomelane and quartz.
10348	,, ,, 47 feet	Braunite, with a little pyrolusite, cryptomelane and quartz.
10349	,, ,, 56 feet	Braunite and quartz, with a little pyrolusite and cryptomelane.
10350	,, ,, 60 feet	Braunite, with a little pyrolusite, cryptomelane and quartz.

D.D.H. No. 2

D.D.H. No. 2 was drilled to 155 feet—20 feet past a small intersection of manganese ore, which is believed to represent the eastern extension of the main ore body. Core recovery was 100 per cent. in the ore and 56 per cent. overall. The main features of the hole were:

1. The discovery of unsuspected ore.
2. The lensing of the main ore body.
3. The presence of chert in the footwall.
4. The abandonment of the hole.

1. The hanging-wall rock intersected in this hole was fine-banded chert and chert breccia. Manganese oxides have replaced the rock in many places and the ore intersection at 43-48 feet and 54-61 feet are in this chert hanging-wall. These ore bodies are replacement deposits in the chert, either as dykes or lenses. The grade of the uppermost body where sampled was 51.9% Mn, 1.38% Fe, and 15.7% SiO_2; and it consisted of braunite, pyrolusite, cryptomelane and quartz, with an increase in the ratio of braunite to pyrolusite from top to bottom.

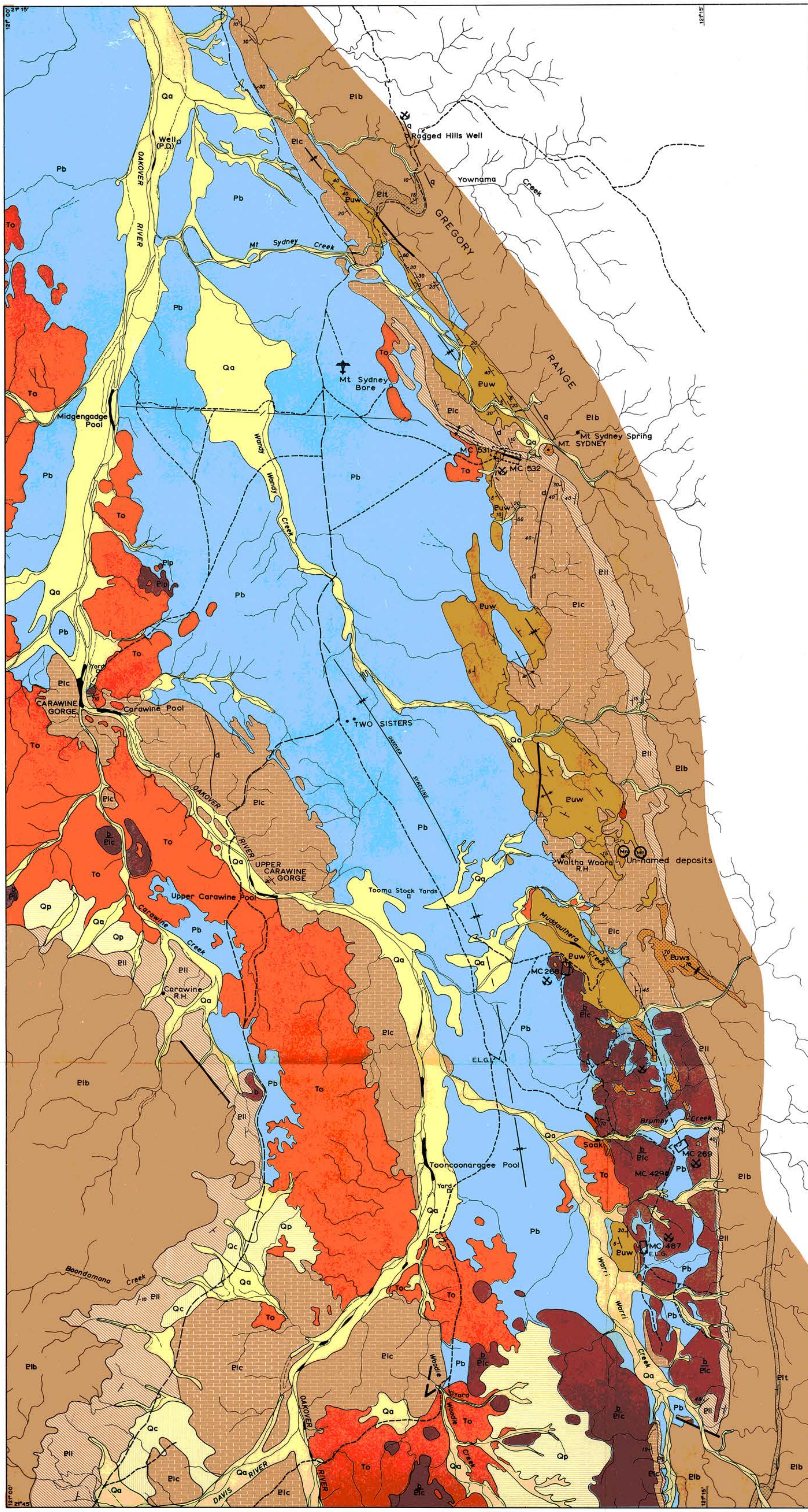
The ore in the second intersection (54-61 feet) has a high silica content, especially in the upper section. There is very little iron in the ore (1.28%) and the average Mn content is about 50%, but the average silica content is 20%. The ore was composed of braunite, minor amounts of pyrolusite and cryptomelane, and variable amounts of quartz.

Further exploration of this ore by wagon drilling is recommended. The ore probably strikes north and it may have any attitude from vertical to horizontal. It does not crop out.

2. Although there are other possible interpretations of the attitude and shape of the main ore body, that shown in the section seems to be the best fit with the intersections in D.D.H. No. 1. The extension of the ore body to the intersection at 134 feet in D.D.H. No. 2 is reasonable since the Carawine Dolomite has variable and low easterly dips in this locality, and it seems that the cavity in which the main ore body was deposited was controlled by bedding. There are also 4-feet gaps (cavities?) in the core, immediately above and below the 134-foot intersection in this hole, as for the main ore body in D.D.H. No. 1.

3. There is far more chert in the footwall in this hole than in D.D.H. No. 2, but there is some dolomite. The quantity of chert is known to be variable in the Carawine Dolomite.

4. At 155 feet the core barrel became inextricably jammed and the hole and barrel were abandoned. A minimum depth of 200 feet had been planned for this hole but as the eastern extension of the ore body had been established in its anticipated correct structural position, redrilling to gain confirmatory evidence over the last 45 feet was not considered necessary.



REFERENCE

CAINOZOIC	QUATERNARY	Qa	Alluvium
		Qp	Sand with laterite pebbles
		Qc	Colluvium
	TERTIARY	To	OAKOVER FORMATION
PALAEOZOIC	PERMIAN	Pb	BRAESIDE TILLITE
PROTEROZOIC	UPPER	Puw	WALTHA WOORA BEDS
		Puws	Sandstone
	LOWER	b	Chert breccia, may include some Tertiary
		Plp	PINJIAN CHERT BRECCIA
		Plc	CARAWINE DOLOMITE with chert breccia, locally
		Pll	LEWIN SHALE
		Plb	LITTLE DE GREY LAVA
		Plt	TUMBIANA PISOLITE MEMBER

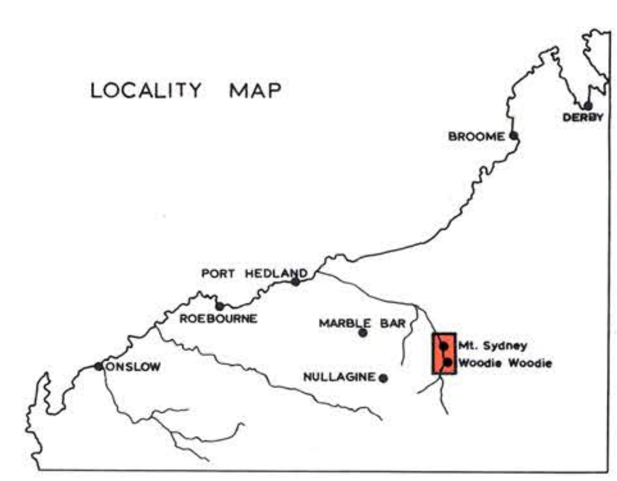
INTRUSIVE

U. PROT.	d	Dolerite dykes

SYMBOLS

Road
Track
River with pool
Bore or well, spring or rockhole
Geological boundary
Strike and dip of bedding
Anticline
Syncline
Fault
Quartz vein
Mineral claim surveyed
unsurveyed
Open cut

LOCALITY MAP



SCALE OF MILES

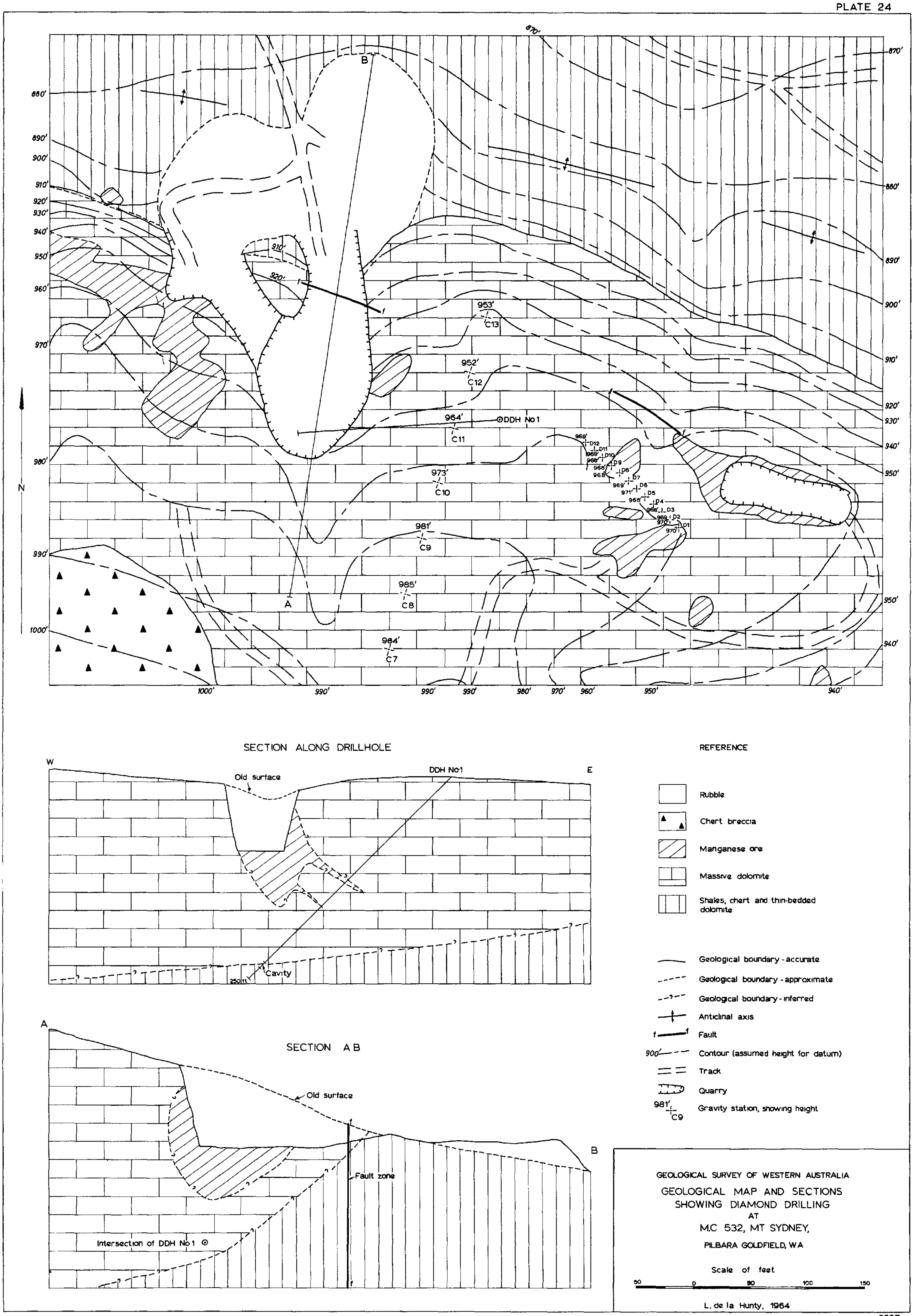
2 1 0 2 4

GEOLOGICAL SURVEY OF WESTERN AUSTRALIA

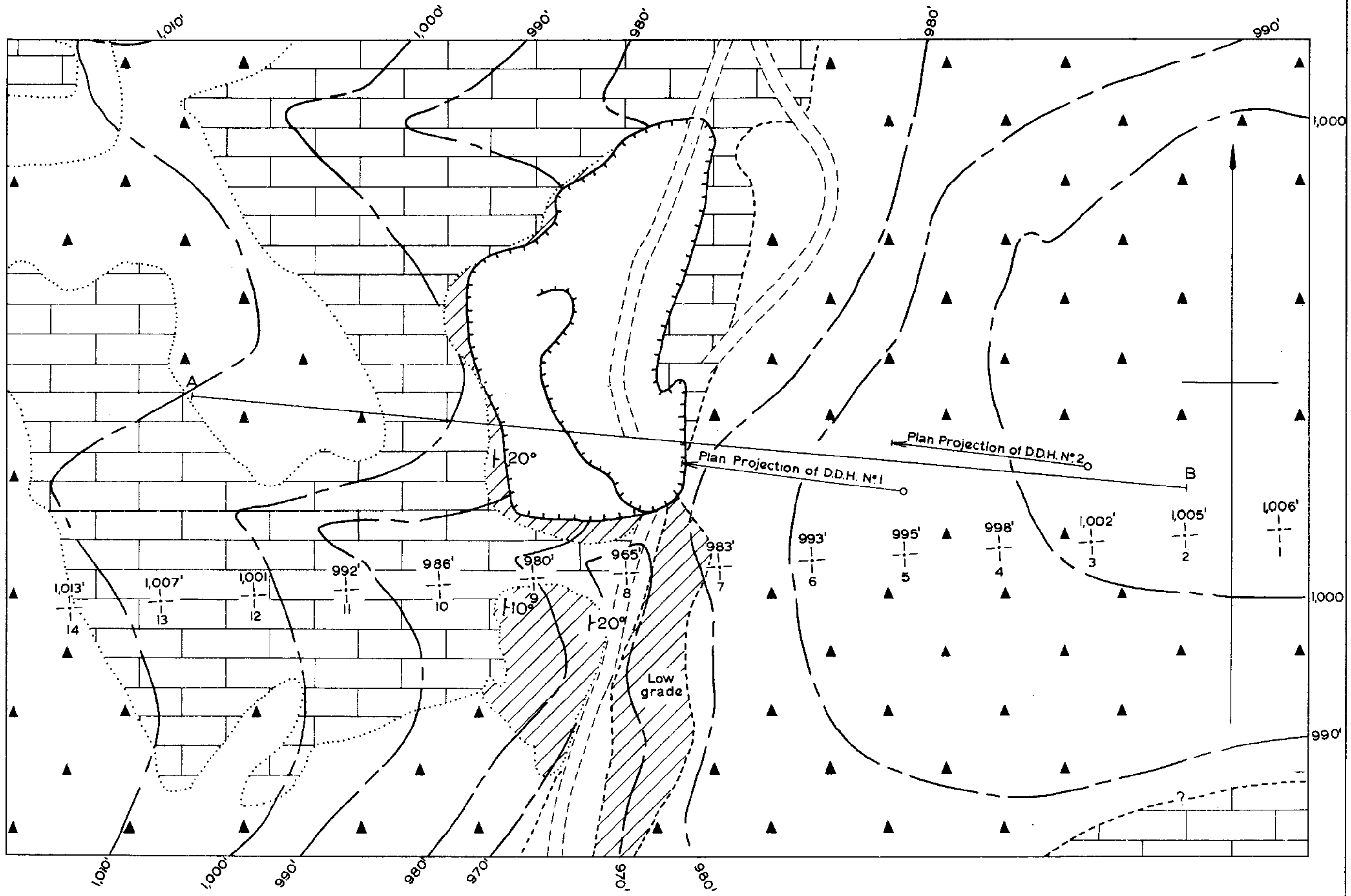
GEOLOGICAL MAP OF MT. SYDNEY-WOODIE WOODIE AREA, PILBARA GOLDFIELD, W.A.

L.E. de la Hunty 1964

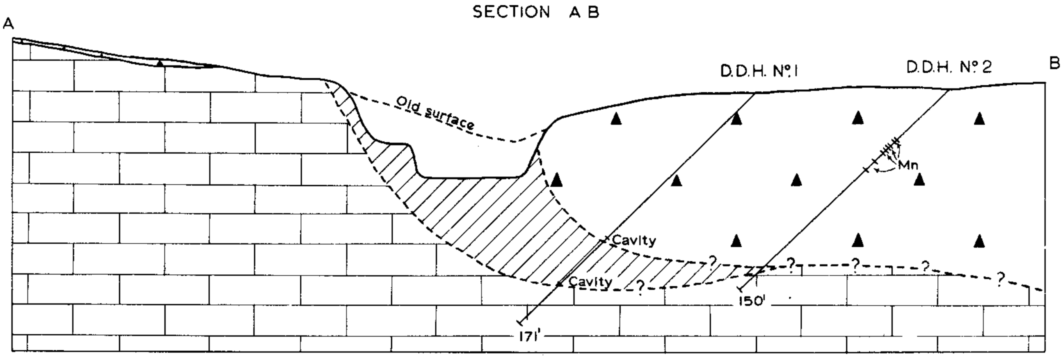
8570


SECTION ALONG DRILLHOLE
W
E
Old surface
DDH No1
Cavity
250 ft
SECTION AB
A
B
Old surface
Fault zone
Intersection of DDH No 1
REFERENCE
Rubble
Chert breccia
Manganese ore
Massive dolomite
Shales, chert and thin-bedded dolomite
Geological boundary - accurate
Geological boundary - approximate
Geological boundary - inferred
Anticlinal axis
Fault
Contour (assumed height for datum)
Track
Quarry
Gravity station, showing height
N
C7
C8
C9
C10
C11
C12
C13
D1
D2
D3
D4
D5
D6
D7
D8
D9
D10
D11
D12
GEOLOGICAL SURVEY OF WESTERN AUSTRALIA
GEOLOGICAL MAP AND SECTIONS
SHOWING DIAMOND DRILLING
AT
M.C 532, MT SYDNEY,
PILBARA GOLDFIELD, W.A
Scale of feet
50
0
50
100
150
L. de la Hunty, 1964

8557



SECTION A B



REFERENCE

	Alluvium and rubble
	Chert and chert brecia
	Manganese ore
	Dolomite

....	Geological boundary-accurate
----	Geological boundary-approximate
--?--	Geological boundary-inferred
1,000'----	Contour (assumed height for datum)
	Track
	Quarry
998' 4	Gravity station, showing height

GEOLOGICAL SURVEY OF WESTERN AUSTRALIA

GEOLOGICAL MAP AND SECTION SHOWING DIAMOND DRILLING AT M.C. 268, WOODIE WOODIE

PILBARA GOLDFIELD, W.A.

Scale of feet

0 25 50 75 100 200

L. de la Hunty, 1964

8556

CONCLUSIONS

1. The manganese deposits in this area were emplaced after the Lower Proterozoic and probably during the Upper Proterozoic Era. They are older than the Waltha Woora Beds.

2. The deposits have been subjected to Permian glaciation and to Cainozoic weathering processes.

3. The deposits occur as cavity fillings in the Carawine Dolomite, and are not the result of supergene enrichment of manganiferous sediments.

4. Some of the ore bodies persist in depth to beyond 100 feet.

5. The drilling on M.C. 532, Mt. Sydney, did not increase the ore reserves and indicated reserves are less than 6,000 tons of high-grade ore.

6. The drilling on M.C. 268, Woodie Doodie, revealed the attitude and grade of the depth extension of the ore body, and increased the indicated reserves to 130,000 tons of ore greater than 50% Mn. A concealed ore body was also intersected.

7. Mining on M.C. 269 did not deplete the indicated reserves during 1964, as new ore was exposed by the operations. Gravity surveys also tended to confirm indicated ore reserves.

8. Gravity testing and mining development on M.C. 487 indicated an increase in ore reserves to several hundred thousand tons of high-grade ore.

ACKNOWLEDGMENTS

The co-operation of the mining companies in the communication of technical information and their assistance in the form of roadmaking, transport of fuel and stores is gratefully acknowledged.

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GRAVITY SURVEY OF MANGANESE DEPOSITS IN THE MT. SYDNEY—WOODIE WOODIE AREA, PILBARA GOLDFIELD

by D. L. Rowston

ABSTRACT

A test geophysical survey over some Pilbara manganese deposits has demonstrated that the gravimeter can detect potential ore bodies. The method is advocated for preliminary assessments of partially concealed deposits prior to drilling and for prospecting other suspected occurrences.

INTRODUCTION

During June 1964 a brief geophysical survey was made over several manganese deposits in the Pilbara Manganese Province to test the effectiveness of the gravity method for detecting and delineating potential ore bodies. The survey was initiated by the Commonwealth/State interest in manganese reserves at the time; the field work was carried out by officers of the Geological Survey of Western Australia with the Worden Gravimeter W.61 on loan from the Bureau of Mineral Resources.

The deposits examined are situated in the Woodie Woodie and Mt. Sydney areas of the Pilbara Goldfield in the North West Division of Western Australia (Plate 23). Manganese is currently mined by open cut methods at Woodie Woodie and transported 230 miles by road to the port of Port Hedland. The geology of most of the deposits, and the area generally, has been described by de la Hunty (1963).

Earlier laboratory investigations indicated a high density contrast (about 1.25) between the manganese ore and country rocks and that the gravity method should therefore be capable of detecting deposits of commercial interest. The method could be particularly useful in assessing whether or not bodies largely concealed by alluvium and detritus warrant test drilling.

FIELD PROCEDURE AND REDUCTIONS

Field work usually consisted of one or more gravity traverses across each deposit; a more comprehensive grid was surveyed at Mineral Claim 269 in the Woodie Woodie area. Gravity station intervals along the traverses varied from 25 to 100 feet depending on the proximity of the body and each station was levelled to an accuracy of 0.01 feet. Base stations were established at the individual localities and reoccupied frequently to determine the drift rate for the meter. These bases were not tied together on a regional scale because of levelling difficulties.

Laboratory determinations of samples of the three principal rock types in the area gave the following average densities: dolomite, 2.84 gm/cc.; chert breccia, 2.64 gm/cc.; manganese 4.12 gm/cc. Whilst the dolomite and breccia gave densities over a narrow range the manganese ore varied widely depending on the grade and amount of siliceous impurity in the sample. Four samples from Mt. Sydney ranged from 3.87 to 4.22 gm/cc. and because similar local variations probably occur elsewhere, an arbitrary density of 4.0 gm/cc. was adopted for the calculations.

A combined free-air and Bouguer correction factor of 0.0600 corresponding to a density of 2.69 gm/cc. was used in the reductions. This value was substantiated by applying Nettleton's technique of least correlation between the topography and corrected gravity results obtained over a ridge of breccia with minor dolomite at Mt. Sydney (Traverse B., Plate 30). This factor also agrees well with the density of the breccia and its application has been justified by the obvious elimination of topographic effects in other localities.

Regional, latitude and terrain corrections are also normally applied to the observed gravity data. However, because of the restricted coverage of the deposits, it was not practicable to compensate for these effects by the standard methods. As most of the traverses were long enough to discriminate between anomalies due to the manganese body and those from deep-seated gravity variations, regional gradients were determined by inspection and the results corrected accordingly. The latitude correction for the area only amounts to a north-south component of about 0.016 milligal/100 ft. and, as most traverses were oriented approximately in an easterly direction, has been neglected. It was not possible to make the detailed topographic surveys necessary for terrain corrections and the lines were disposed to minimise these effects.

INTERPRETATION OF RESULTS

The interpretation of a gravity anomaly consists essentially of assuming some simple geometrical and geologically plausible form for the body and calculating a theoretical anomaly for this body. The theoretical anomaly, usually a sectional profile, is then compared with the observed gravity and discrepancies removed by successive modification of the original model until a "best fit" between observed and theoretical curves is obtained. Under normal conditions there is no unique solution to a particular gravity problem but the inherent ambiguity in interpretation can be reduced by geological control. The major unknowns are the depth, density contrast, shape and size of the body. All the deposits investigated during the survey occur at or near the surface and the uncertainty of the depth factor has been thus practically eliminated. A density contrast of 1.25 has been employed for the calculations and is considered to be a realistic approximation in the absence of more comprehensive density data. The objectives of the survey were to determine the shape and size of the body.

The calculations of gravity profiles for the simple two dimensional forms were made with the standard dot chart; it is assumed that the bodies extend to infinity in the third dimension and end effects have been ignored. In the case of the finite vertical cylindrical form at M.C. 487 the theoretical anomaly was calculated by the method of solid angles detailed by Nettleton (1942). It is emphasised that the solutions given are only approximations compatible with the preliminary nature of the work.

Two estimates of the probable tonnages of manganiferous material available from the deposits at M.C. 269 and M.C. 487 were made by the method of total anomalous mass described by Parasnis (1962.) It was necessary to interpolate residual gravity values to complete grids about the two deposits and at M.C. 487, to assume circular symmetry to use the method.

DISCUSSION OF RESULTS

The localities of the various mining tenements investigated during the survey are shown on Plate 23. They are M.C. 269, M.Cs. 531, 532, M.C. 268, M.C. 487, M.C. 429 and an unnamed prospect.

Plates 26 to 31 show the corrected gravity results in the form of Bouguer and residual contours and/or profiles. Where interpretation has been practicable, the profiles include the theoretical gravity curve for comparison and the assumed geological section from which the theoretical gravity was obtained.

M.C. 269

This tenement is just south of the Woodie Woodie ore body currently being worked by Mt. Sydney Manganese Pty. Ltd. The deposit has been tested by wagon and diamond drilling and the overburden partially removed. Gravity datum for the investigations was the northwestern lease peg from which the grid centreline was surveyed on a magnetic bearing of 104.5 degrees; six traverses spaced about 100 feet apart and up to 600 feet in length were pegged at right angles to the centreline.

The Bouguer and residual gravity contours of the gridded area (Plates 26, 27) contain a well defined lenticular anomaly which conforms in part with the postulated geological outline of the manganese deposit and attains a maximum of 0.85 milligal. The 0.4 milligal contour which approximately delineates the boundary of the manganese body extends over a distance of 400 feet from Line B to Line F with no definite sign of closure at the eastern end. Mullock dumps and the open cut precluded additional work to find the eastern extremity of the deposit.

Drilling has indicated that much of the manganese is ore grade although the quality is variable, ranging from about 31 to 50 per cent. manganese with the poorer grades towards the margins of the body. As far as is known the ore body is surrounded by glacial deposits and is partly associated with the Carawine Dolomite, an environment similar to that of the adjacent ore body.

According to the gravity data, both contours and profiles, the most massive part of the body lies between Lines F and D. From Line D it either plunges beneath the surface at the western end or becomes a sheetlike deposit; it is most likely that the body terminates somewhere between Lines C and B and that the minor anomaly on Line B is due to end effects. This purely geophysical interpretation is at variance with the drilling information which shows that ore was encountered from the surface to a depth of 35 feet in two holes near stations C/00 and B/00. Despite this evidence it is difficult to reconcile the observed gravity of Line C with a surface sheet to produce a better fit than that given for the assumed section on Plate 29. Selection of the other theoretical body for Line E was guided by drillhole intersections with the ore body; two holes put down to the north and south of station E/00 encountered 82 and 34 feet of manganese. Excellent agreement between the observed and calculated gravity was obtained using a density contrast of 1.25.

Calculation of the probable tonnage of manganiferous material contained in the area of the gravity survey, derived by Parasnis's method of total anomalous mass for a 100 foot grid, gave a figure of 400,000 tons. An ore body of this size could have dimensions of 100 by 80 by 450 feet which is not unrealistic. However, this figure is only an approximation because of the meagre density data of the manganese body and host rock. Much of the manganese would not be classed as ore grade.

M.Cs. 531, 532

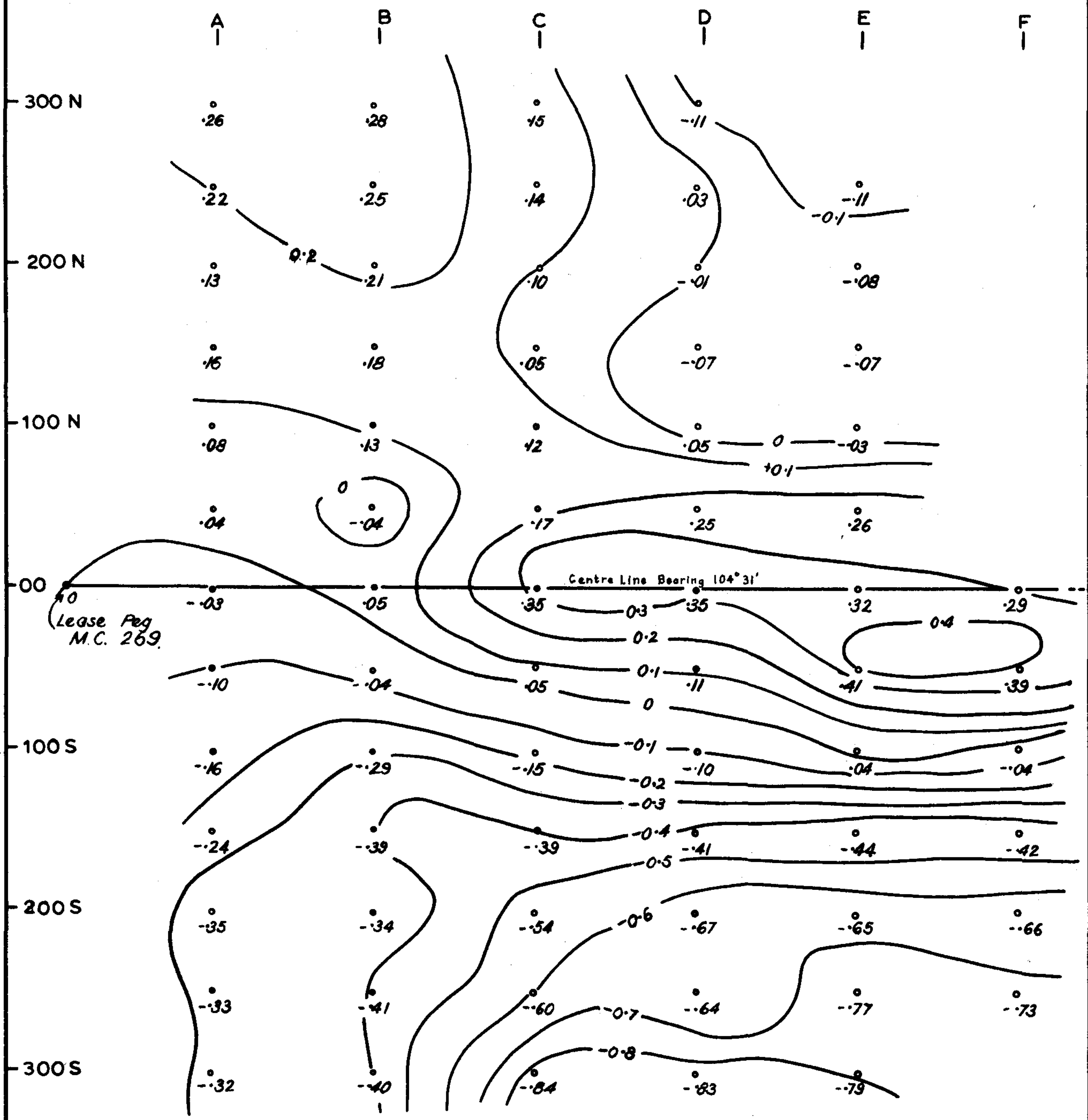
At Mt. Sydney where the main ore body occurs as a cave or fissure filling in the Carawine Dolomite the gravity results were inconclusive. The rugged topography precluded an adequate investigation of the deposit, and terrain effects may contribute largely towards the 0.3 milligal anomaly obtained on traverse C (Plate 30). Neglecting terrain effects and assuming a density contrast of 1.25, this broad anomaly could arise from a horizintal cylindrical body of manganese with a radius of 35 feet and depth to centre of 70 feet. However, detailed gravity and topographic surveying beyond the scope of the test survey are required before any definitive interpretation can be made. Traverses A and B were occupied to obtain an elevation correction factor for the area and are not associated with the manganese deposit.

M.C. 268

M.C. 268 has been mapped geologically (de la Hunty, 1963) and partially mined. Two diamond drillholes were proposed to investigate the possible easterly continuation of the ore body beneath a chert breccia ridge and the gravity traverse was oriented to take advantage of this future information. The observed gravity profile (Plate 30) contains an anomaly of about 0.1 milligal, which under normal circumstances, would be considered insignificant and bordering on the magnitude of reading and corrections error. However, the the subsequent drilling revealed about 30 feet of managanese at the breccia-dolomite contact and, considering the uniformity of the remainder of the gravity profile, the minor anomaly is ascribed to the ore. With the interpolation of station 00 accepted, the anomaly could be due to a theoretical horizontal cylinder with a radius of 20 feet and depth to centre of 60 feet.

M.C. 487

The circular mesa of manganese outcropping at this tenement and rising some 30 feet above the surrounding scree covered country had not been exploited or tested geologically. Two parallel traverses A and B were surveyed to investigate the deposit. Traverse A, directly across the centre of the outcrop, resulted in a residual gravity anomaly of about 1.0 milligal attributable to the manganese (Plate 31). Traverse B was occupied to determine whether or not the manganese continued beneath the scree cover to link with



LEGEND

·41 Gravity Station & value (milligals)

Contour interval : 0·1 milligal

Regional correction : 0·125 mg/100 feet N-S

Elevation correction factor : 0·060 mg/ft

Gravity datum : Lease Peg

Centre line bearing 104°30′ magnetic

GEOLOGICAL SURVEY OF WESTERN AUSTRALIA

GRAVITY SURVEY WOODIE WOODIE AREA - M C 269

GRAVITY CONTOURS — BOUGUER ANOMALY

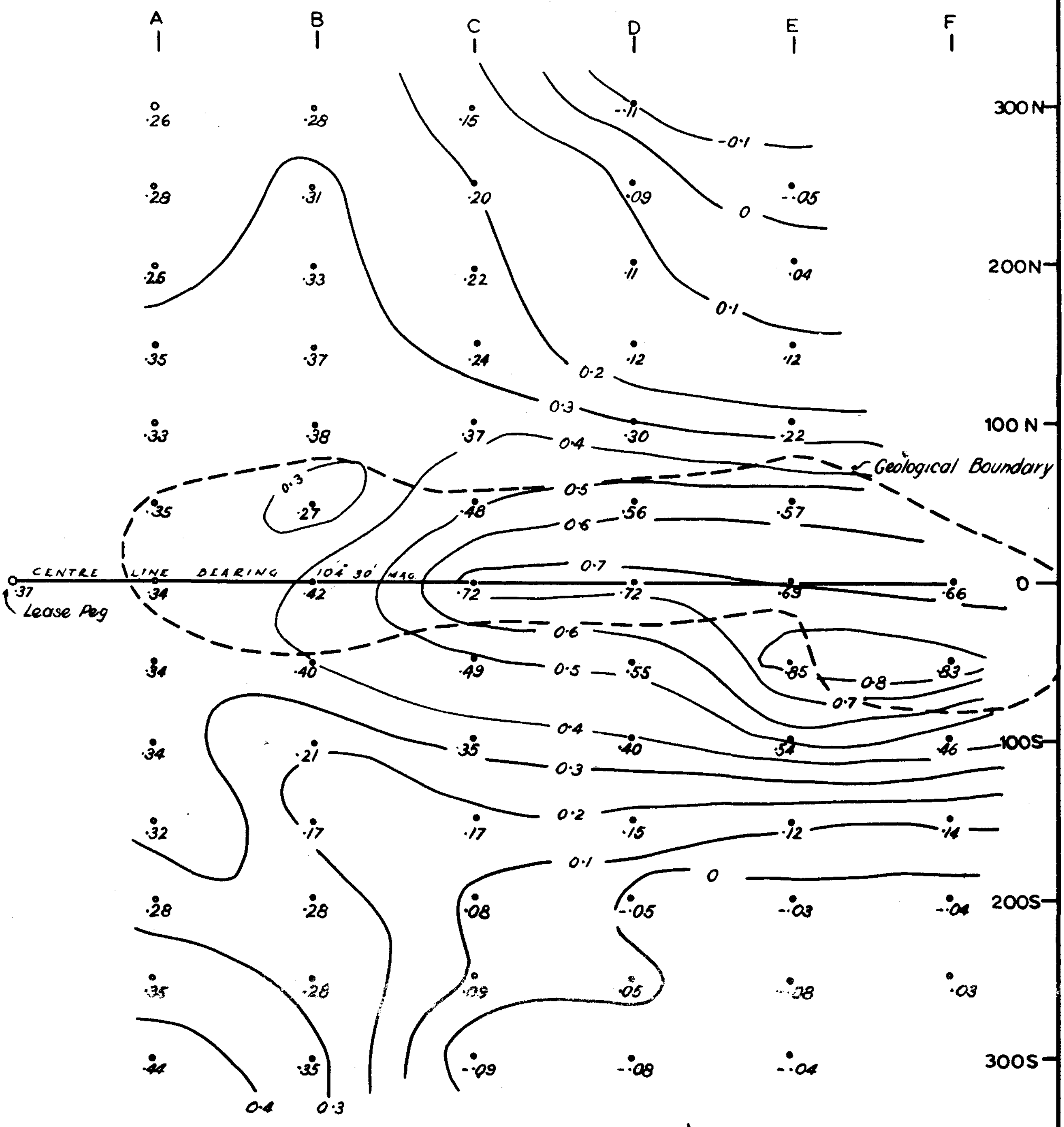
Scale in feet

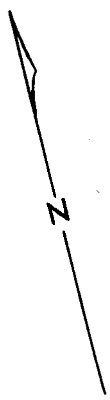
100 50 0 100 200

To accompany report by D.L.Rowston, 1964

8629

PLATE 27





LEGEND

- ·41 *Gravity Station & value (milligals)*
- *Contour interval: 0·1 milligal*
- *Regional correction: 0·125 mg/100 feet N-S*
- *Elevation correction factor: 0·060 mg/ft.*
- *Gravity datum: Lease Peg*
- *Centre line bearing 104°30' magnetic*

GEOLOGICAL SURVEY OF WESTERN AUSTRALIA

GRAVITY SURVEY WOODIE WOODIE AREA - M C 269

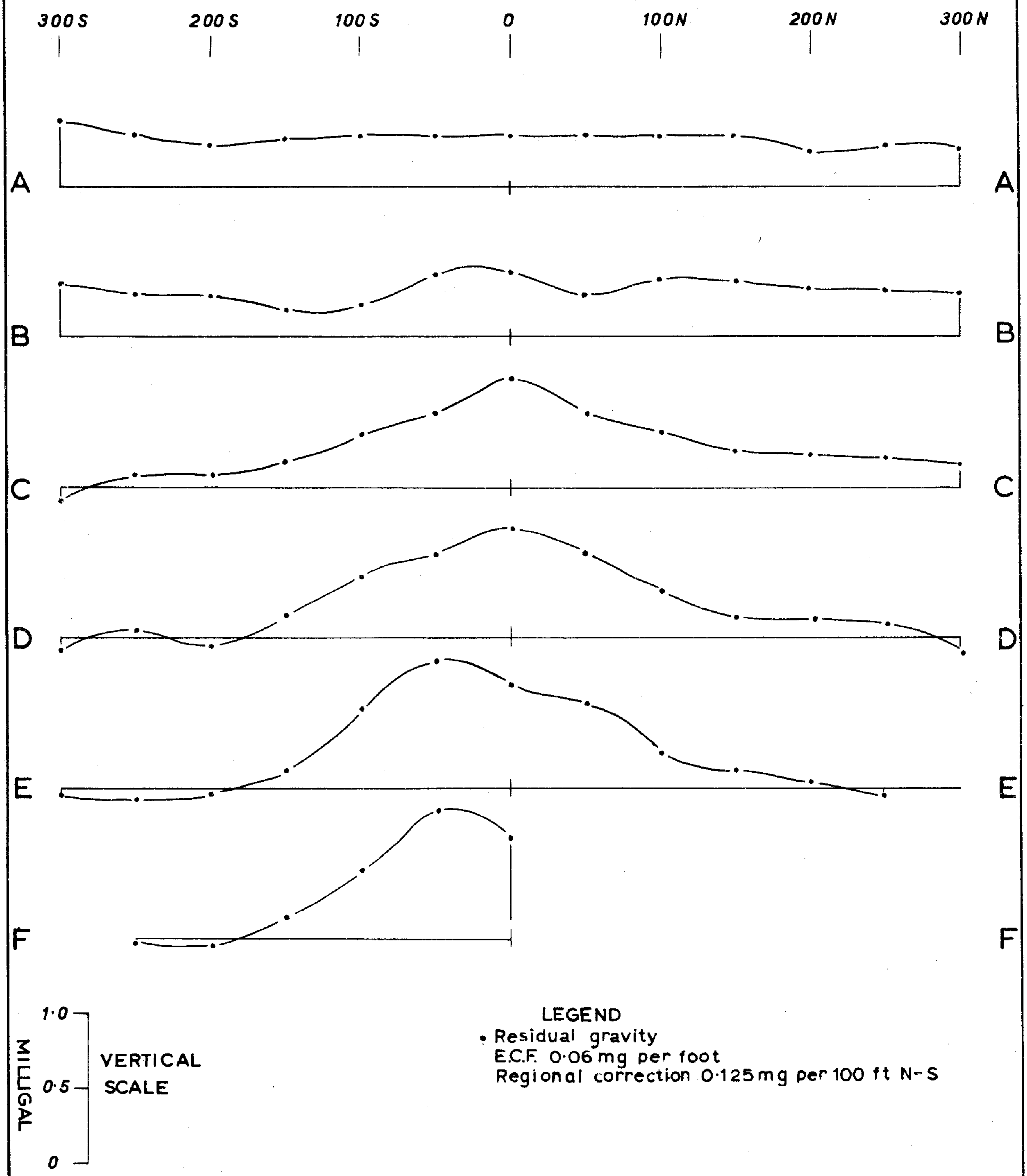
GRAVITY CONTOURS — RESIDUAL ANOMALY

Scale of feet

100 50 0 100 200

To accompany report by D.L.Rowston, 1964

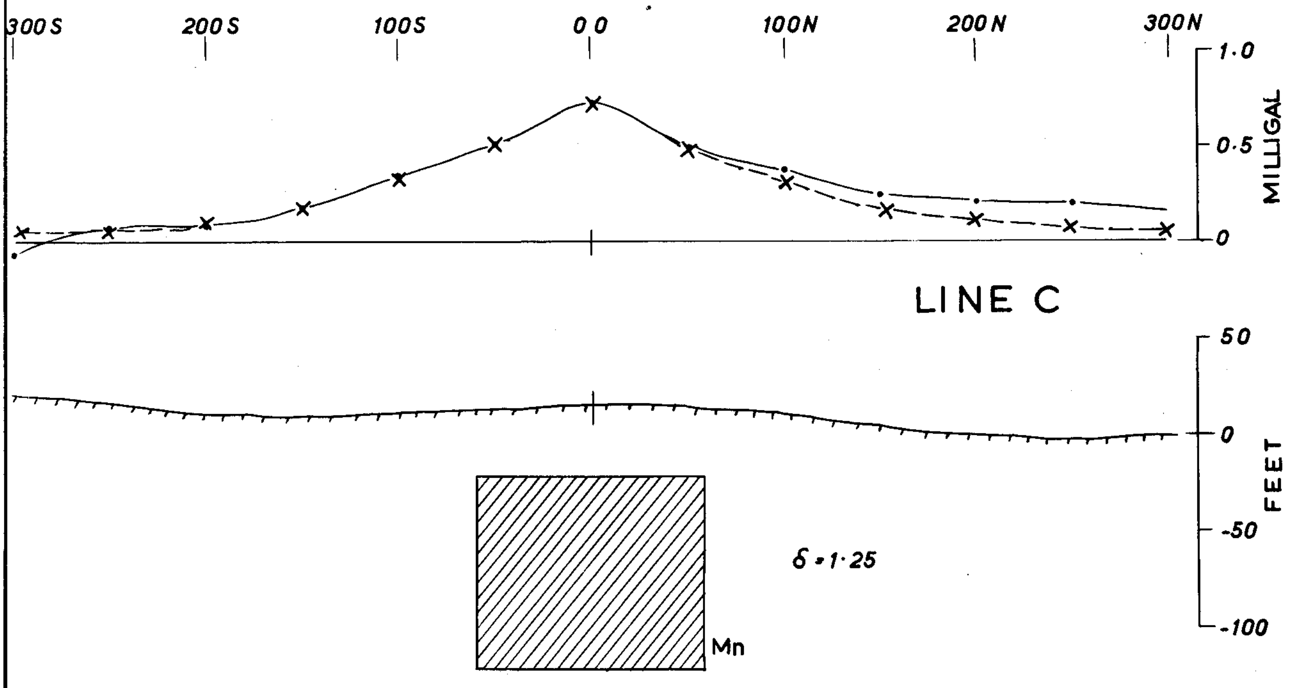
8630

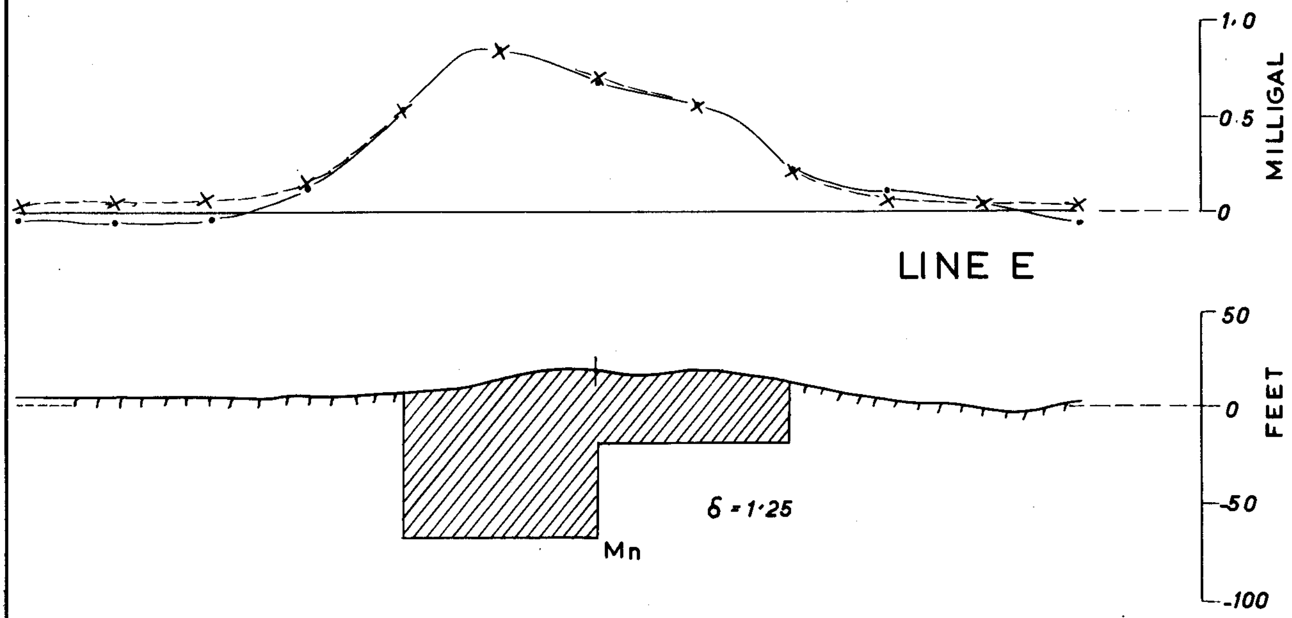


GEOLOGICAL SURVEY OF WESTERN AUSTRALIA

GRAVITY SURVEY, WOODIE WOODIE AREA M C 269
RESIDUAL GRAVITY PROFILE

To accompany report by D.L.Rowston, 1964





LEGEND

· Residual gravity

× Computed gravity

▨ Theoretical two dimensional body

E.C.F. 0·06 mg per foot

Regional correction 0·125 mg per 100 ft. N-S

GEOLOGICAL SURVEY OF WESTERN AUSTRALIA

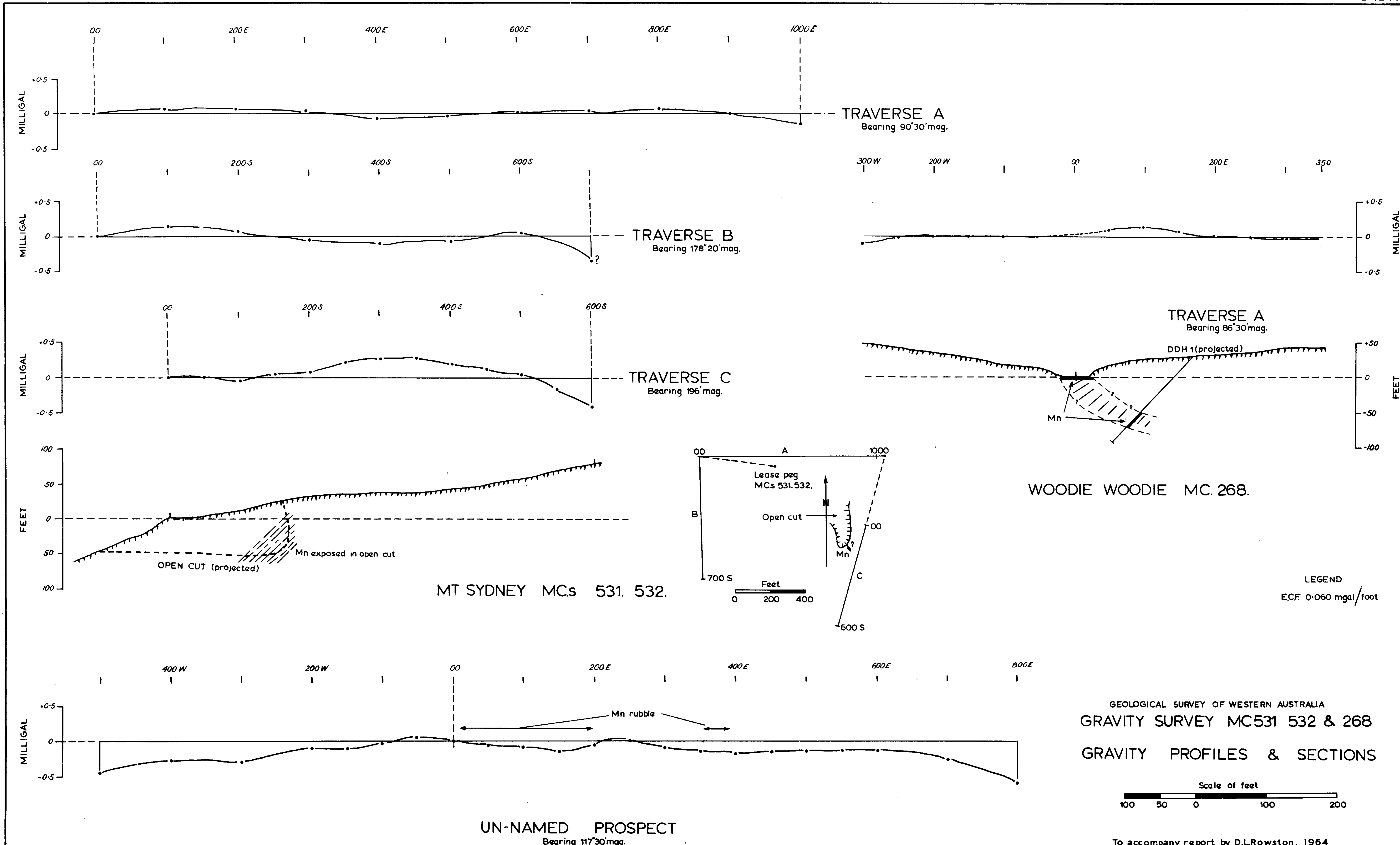
GRAVITY SURVEY, WOODIE WOODIE AREA - M C 269
RESIDUAL AND THEORETICAL GRAVITY PROFILES

Scale of feet

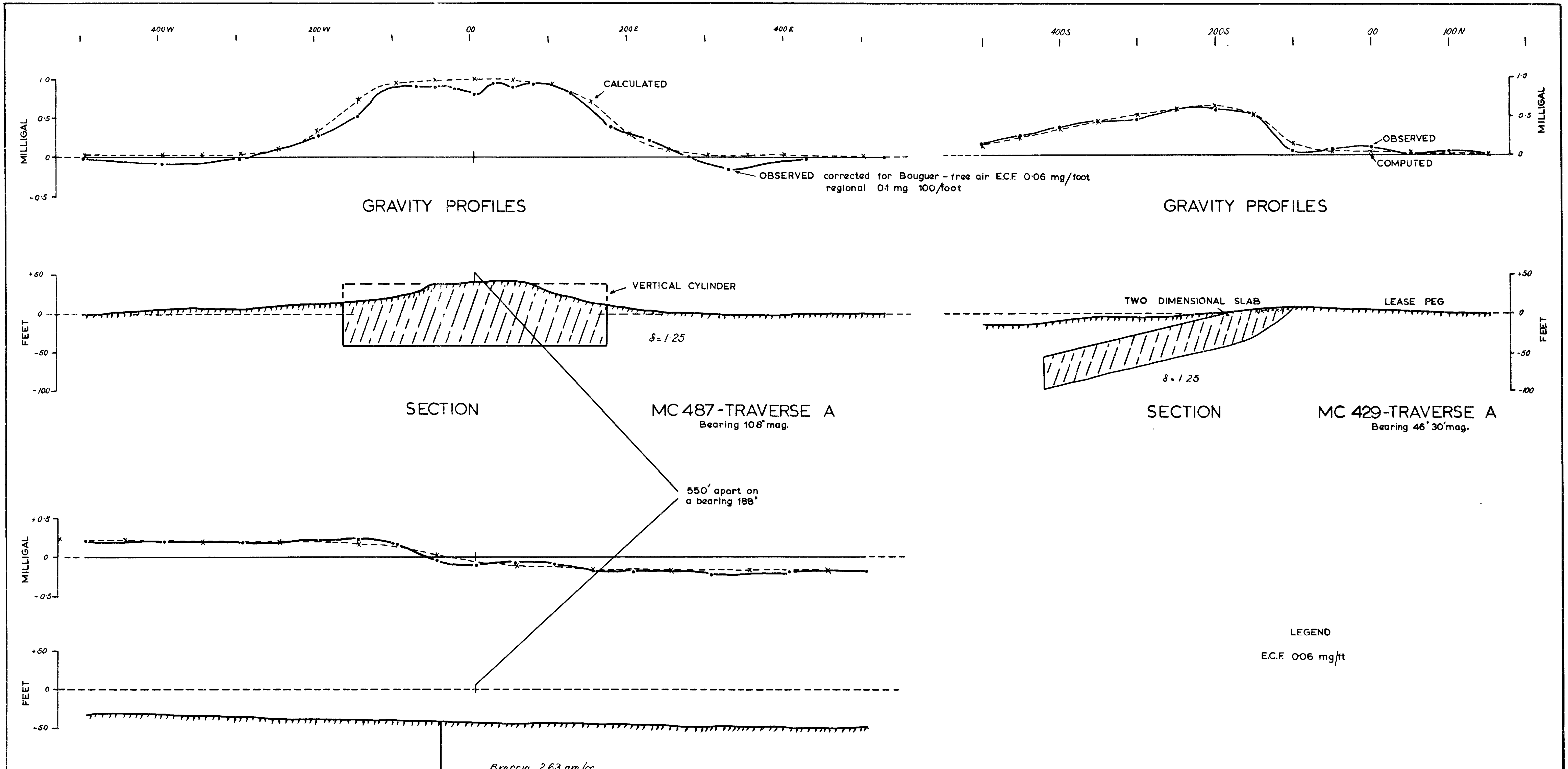
100 50 0 100 200

To accompany report by D.L.Rowston, 1964

PLATE 30



8376



GEOLOGICAL SURVEY OF WESTERN AUSTRALIA

GRAVITY SURVEY WOODIE WOODIE AREA

MC 487 MC 429

GRAVITY PROFILES & SECTIONS

To accompany report by D.L. Rowston, 1964

8377

another prominent outcrop to the south; the minor anomaly on this traverse indicates a probable geological contact or fault at about the point of inflection of the anomaly but contains no evidence of manganese.

The theoretical solution of traverse A was calculated for a finite vertical cylinder of radius 170 feet and thickness of 80 feet assuming a density contrast of 1.25. At three tons of manganese to the cubic yard and with due allowance for the annulus removed by weathering the body contains about 660,000 tons of manganiferous material. Another estimation of the possible available tonnage was made from the total anomalous mass on the assumption of circular symmetry of the gravity data. The figure of 690,000 tons obtained agrees substantially with the previous estimate. It is emphasised however, that these tonnages are only approximations because of the paucity of gravity data and density control.

M.C. 429

This one acre claim pegged about a small outcrop of manganese was investigated by one gravity traverse 650 feet long on a magnetic bearing of 46.5°. The Bouguer anomaly profile shown on Plate 31 indicates either a fault contact or a dipping two dimensional slab. In the absence of surface geology, interpretation has been based on the latter and the theoretical body to give a best fit solution is depicted in the section. Although this solution is regarded as conjectural, the deposit warrants further examination either by drilling or gravimeter, because of its proximity to the current mining operations at Woodie Woodie.

UNNAMED DEPOSIT

Two small outcrops situated in undulating country some 2.7 miles north-northeast of M.C. 268 were tested by a traverse 1,300 feet long on a magnetic bearing of 117.5°. Although two small gravity maxima were detected the profile (Plate 30) does not appear to indicate a deposit of commercial interest.

CONCLUSIONS AND RECOMMENDATIONS

The test geophysical survey has demonstrated that the gravity method can be usefully applied to investigate manganese deposits in the Pilbara area and elsewhere.

The method is rapid and, compared to the usual alternative of drilling, relatively inexpensive. Whilst drilling is an essential in any final assessment of a manganese deposit as an economic proposition, preliminary gravity work can indicate whether or not drilling is warranted and can be used to select drilling tragets. This applies particularly to those deposits where surface alluvium and detritus prevents a geological appraisal.

The somewhat tentative interpretations of the gravity anomalies obtained during the test survey could be refined considerably and more accurate estimates of probable tonnages made, if time had been available to extend the gravity coverage and collect more manganese samples for density determinations.

Future preliminary investigations of a manganese prospect should include at least three gravity traverses; two across the strike of the outcrop and another longitudinally. Any residual anomaly exceeding about 0.3 milligal should then be systematically gridded at about 50 or 100 foot intervals to enable a thorough interpretation of the results. Comprehensive sampling of the manganiferous and country rocks will give better density control and also provide a possible correlation between density and grade.

The gravity results indicate that, excluding the deposit at M.C. 269 which is to be exploited, the manganese bodies at M.C.s 487 and 429 warrant further examination as possible sources of manganese.

A more detailed description of the gravity survey and its results is given by Rowston (1964).

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PISOLITIC TUFFS IN WESTERN AUSTRALIA

by A. F. Trendall

ABSTRACT

Tuffs containing discrete pea-like aggregations of fine-grained tuff (pisoliths) in a tuff matrix occur in the Precambrian Fortescue Group of the Pilbara area, at two main stratigraphic levels with a lateral extent of over 300 miles. At these levels, beds of pisolitic tuff are distributed irregularly within a greater thickness of similar but non-pisolitic rocks. The average diameter of pisoliths varies between 1 and 13 mm and they have a small range of size in any one bed. Commonly they are close-packed in thin homogeneous beds without internal stratification, but other varieties show effects of current sorting. Diagenetic replacement of the matrix by calcite shows that most originally spherical pisoliths have been deformed by late compaction to oblate ellipsoids with elongation ratios between 1.40 and 1.75. Accretion of moist ash in eruptive clouds with consequent fall of mud-pellet rains has been suggested for closely similar rocks in the United States. An origin by colloidal flocculation of the finest material in subaqueous, originally non-pisolitic, tuff close to the sediment-water interface is favoured by the evidence from Western Australia, but more work is required for reasonable certainty.

INTRODUCTION

Pisolitic tuffs are tuffs which contain discrete pea-like aggregations of fine-grained material known variously as accretionary lapilli, chalazoidites, fossil raindrops, mud balls, mud pellets, volcanic hailstones and volcanic pisolites; here they are called volcanic pisoliths or simply pisoliths. The purposes of this report are: (1) to record the occurrence of these rocks in Western Australia, (2) to review past and current references to them by geologists of the Survey, (3) to list specimens of pisolitic tuff in the registered rock collection of the Survey, (4) to describe briefly these specimens, (5) to note published references to similar rocks, and (6) to comment briefly on their origin and significance.

OCCURRENCE

Except for a single example, noted below, all the known pisolitic tuffs of Western Australia occur within the Fortescue Group (MacLeod and others, 1963). This is the lowest stratigraphic division of a thick sequence of comparatively undisturbed Precambrian sediments and volcanics which in the Pilbara area (here considered as approximately lats. 21°-23°S, longs. 116°-121°E) unconformably overlies the Pilbara System, an older Precambrian complex of folded sediments, volcanics and intrusive granites. The Pilbara System appears to be about 2,900 m.y. old in part, while acid volcanics 20,000 feet above the basal unconformity of the Fortescue Group have an age of 2,100 m.y. (Leggo and others, 1965).

The Fortescue Group (Kriewaldt, 1964) has an average thickness of 3,000 feet of alternating tuffs, basic lavas and shales. Although correlation within the group is still tentative, pisolitic tuffs are known to occur within two main stratigraphic units, and other minor developments are reported. The upper unit, which in the east is split by a lava about 200 feet thick, is separated by 600-700 feet of lava from the lower. The upper is continuous from east to west for over 300 miles, and the lower for some 130 miles.

The pisolitic tuffs occur within stratigraphic units up to 2,000 feet thick which include shales, sandstones, conglomerates, jaspilites, minor lavas, dolomites and pyroclastics varying from silt grade to agglomerate. Rough estimates of the proportions of pisolitic tuffs in these formations suggest about a tenth of their thickness, and the total of such beds in the Fortescue Group is probably between 100 and 200 feet.

Even at those levels within these formations at which pisoliths are common they are distributed sporadically in beds up to 2 feet thick, but generally less, separated by non-pisolitic tuffs. The shape of individual pisolitic beds is not known, but beds inches thick certainly extend laterally for hundreds of feet.

An exceptional specimen (R709) comes from the underlying Pilbara System, ¼ mile north of Warambie Homestead, at approximately lat. 20° 57′ S, long 117° 22′ E. Although pisolitic tuff in this System is known only from this single locality, the occurrence is significant in showing that, whatever were the conditions under which these rocks were formed, they existed some 2,900 m.y. ago.

PAST AND CURRENT WORK

Amygdaloidal lavas recorded by Maitland (1908, p. 125) from Wild Dog Camp are pisolitic tuffs of the Fortescue Group. Talbot (1920, p. 132) later described a 40 foot-thick limestone between lavas which Farquharson (in Talbot, 1920) noted was oolitic. The specimen referred to (13976) is a laminated non-pisolitic tuff; there has probably been a later confusion of numbering. Noldart and Wyatt (1962, p. 66, 67, 80) later formally named the formation from which Maitland's and Talbot's specimens came as the Tumbiana Pisolite (misspelt "Tumbinna" Pisolite throughout their publication), and de la Hunty (1964) mapped the same formation in an adjacent area. All this work was done near the eastern end of the Fortescue Group outcrop.

Later mapping has extended the known outcrop of pisolitic rocks some 300 miles westwards; they occur in the Mt. Herbert Tuff (which is correlated, at least in part, with the Tumbiana Pisolite) and in the Cliff Springs Formation, a second pyroclastic unit lying at the base of the Fortescue Group (de la Hunty, Kriewaldt, Ryan, Williams; pers. comm.). Realisation of the tuffaceous nature of these pisolitic rocks came during this mapping through their constant volcanic association and by petrological examination. Further references to these rocks will appear in the Explanatory Notes of the Roy Hill, Pyramid, Mount Bruce, and Yarraloola 1:250,000 Geological Sheets.

MATERIAL AVAILABLE

The registered rock collection of the Geological Survey of Western Australia contains 37 specimens of pisolitic tuff collected over 60 years; all but one (R709) of these come from the Fortescue Group. The numbers of these specimens are:

5808	2/4698	2/4699	2/4700	2/4701	2/4702
2/4073	2/4705	2/4707	R35	R36	R68
R371	R709	R712	R964	R965	R966
R972	R985	R1006	R1021	R1053	R1087
R1101	R1102	R1106	R1110	R1203	R1204
R1205	R1206	R1207	R1208	R1209	R1210
R1211					

DESCRIPTION OF THE PISOLITIC TUFFS

The various textural and compositional characters of the Western Australian tuffs, as expressed in the specimens listed above, are described below:

Composition of the Rocks

As emphasized below, matrix and pisoliths in any one rock have the same composition, and this description applies to both. The distribution of coarse and fine material is described under "Internal Structure of the Pisoliths".

The rocks are fine-grained tuffs in which the coarsest fragments (R1006) reach 2mm; but generally, in even the coarser-looking rocks (R1101, R1102), the largest grains are no greater than 0.5 mm across. Fragments as large as this never constitute a large proportion of the rock, and there is a continuous downward gradation to irresolvable material. In many specimens (e.g. R1087) no fragments larger than 0.1 mm occur. The recognisable fragments consist of subangular and sharply angular broken grains of quartz, microcline, albite, cloudy alkali feldspar, elongate prisms of green amphibole, subrounded to subangular rock (chert, quartzite, ?rhyolite) fragments, and typically curved and pointed shards of volcanic glass devitrified to an isotropic mosaic of colourless chlorite. The fragments in one rock may be almost entirely quartz and feldspar (R1006), mainly shards (R1110) or a mixture of the two. Small ilmenites, often embayed by later alteration, are sometimes present (R371; R965).

All the finer parts of these rocks are now represented by a dense aphanitic aggregate of quartz, chlorite, sphene, ?sericite and ?amphibole in which individual grains are difficult to distinguish although the original structures of the rock are defined by lighter and darker patches. More detailed descriptions are given (R35, R68) in unpublished Petrologist's Reports Nos. 6 and 9 of the Geological Survey of Western Australia.

It is noteworthy that pisoliths only occur in the acid tuffs intercalated between basic lavas.

Size and Shape of Pisoliths

The mean apparent greatest diameters of 20 pisoliths each from five specimens (R964, 2/4699, R371, R1204, R1102) are 1.38, 3.81, 4.84, 8.23 and 9.62 mm repectively, measured on a face perpendicular to the bedding. A subjective assessment of these five rocks is that the true mean greatest diameters would be about a third greater than these figures, giving a size range in this group of less than 2 to about 13 mm. R1102 has the largest pisoliths of the whole collection but others not measured (R1205, R1208) have pisoliths of average diameter about 1 mm.

Almost all complete pisoliths in the collection, including those of the five measured specimens above, are oblate spheroids with their shortest axes within about 20° of a normal to the bedding plane; exceptions are the current-modified 2/4700 and 2/4701 (see below) and R35, in which the longest axes of the elongate pisoliths lie at about 25° to the bedding owing to deformation during folding. In the five measured specimens listed above the mean elongation ratios for 20 pisoliths are 1.08, 1.08, 1.40, 1.75 and 1.42 respectively; the significance of these figures is discussed below.

Sorting of Pisoliths

In most specimens there is little range in pisolith diameter; few depart more than ± 10% from the mean. In 2/4706 a plane of stratification is defined clearly by a sharp change in average pisolith diameter from about 1.5 to 3.0 mm. R35, R371 and R1204 show this limitation of size range particularly well. In R1208 a single pisolitic bed 3.5 mm thick shows a steady gradation from a basal average diameter of nearly 2 mm to an uppermost diameter of about 1 mm.

Volume and Distribution of Pisoliths

In the bulk of the specimens (particularly good examples are: 5808, 2/4699, 2/4700, 2/4706, R35, R371, R964, R1021, R1102, R1203, R1208) the pisoliths are more or less tightly packed, and therefore of necessity evenly distributed in a rock with little internal evidence of stratification. Point counts (using a 2 mm grid over at least 30 cm²) of five of these gave percentage volume estimates as follows:

Specimen	Matrix	Pisoliths
R 371	18	82
R 1021	37	63
R 1102	50	50
R 1203	30	70
R 1204	26	74

The figures for R1204 fall close to the theoretical 25.9 and 74.1 for close-packed spheres, while those for R1021 and R1203 indicate little separation of pisoliths. The 82% pisolith volume of R371 is probably due to mutual plastic yielding of pisoliths in contact. R1102 shows a larger departure from close-packing which is confirmed by inspection of the specimen.

In three rocks (R712, R1206, R1210) pisoliths are scattered irregularly in a fine-grained tuff, although in one of these (R1206) they tend to be concentrated in bands parallel to the bedding. In four specimens (2/4700, 2/4701, R1203, R1207) there is evidence of current action; in three of these current-modified rocks (all except R1207) the pisoliths are closely associated with finely laminated siltstone. Pisoliths are truncated (2/4700), squashed into unusual irregular shapes (2/4700, 2/4701) or broken (all four specimens). In R1203 pisoliths appear to have been trapped in the troughs of current ripple marks.

Composition and Internal Structure of Pisoliths

The composition of the pisoliths is always exactly the same, except for a greater proportion of fine material, as that of the matrix. Thus if shards are the main fragment type in the matrix (R1110) this is also true for the pisoliths; if ilmenite grains are present in the matrix (R965) they are present in the pisoliths also. In no slide has it been possible to find any detail in which matrix and pisolith differ.

In the structurally simplest pisolith there is a sharply defined edge of fine material which grades evenly inwards to a core of structureless tuff of similar grain-size to that of the matrix. The main variants are:

1. There may be at the core a single coarse grain giving the effect of a nucleus. A sequence of close parallel cuts across R1102 showed that in this rock such nuclei were present in about half of the pisoliths only.

2. There may be little or no inward increase of grain-size, so that the pisoliths are almost homogeneous spheroids of structureless fine tuff. This type occurs in rocks of both coarse matrix (R985) and relatively fine matrix (R1204).

3. Alternatively the grading may take place over a small fraction of the radius, so that a thin outer shell of very fine material encloses homogeneous tuff like that of the matrix (2/4701, R1053).

4. There may be a repetition of the grading sequence to give alternations of fine and coarse tuff (up to 7 observed—R1101). Where there are several rings the finest tuff is always peripheral.

In all pisoliths any elongate fragments present have their long axes arranged tangentially to give a concentric pattern.

Broken and Modified Pisoliths

In several specimens (2/4700, 2/4701, R36, R709, R1006, R1053, R1087, R1101, R1102) broken pisoliths appear in association with whole pisoliths. The breaking appears to be divisible into three types:

1. In 2/4700 and 2/4701 the pisolitic tuffs are current-modified types in which the pisoliths are defined by thin peripheral shells. A few of these are broken and it is clear from the arangement of the pieces that the pisoliths have been crushed in place during current sorting.

2. In others (e.g. R36, R709, R1053) there is a fairly equal and homogeneous mixture of whole and broken pisoliths closely packed in either a fine-grained tuff or a calcite matrix. In both R709 and R1053 it is clear that some of the fracturing took place in situ, possibly during mass preconsolidation movement of the rock unconnected with current action. In R36 the fracture seems to have taken place right across internally competent pisoliths, while in R1053 the shapes give the impression that a competent skin surrounded a plastic core, since although the outer shell is cracked there is no sign of fracture in the interior.

3. In R1102, the specimen with the largest pisoliths, evenly distributed through the rock and occupying half of the volume, the pisoliths show variable states of modification. Some have segments cleanly removed, with truncation of interior rings. In others, outer layers of the pisoliths are partly stripped. In others, outer layers are indented and deformed, while inner rings are perfectly circular. Few have escaped minor injuries of some kind.

Incipient Pisoliths

In a few specimens (e.g. R966, R1106, R1110, R1206) which have well developed pisoliths, a transition can be followed through successively less well defined pisoliths into vague spheroidal structures which, in a rock lacking pisoliths, would pass unnoticed.

Calcite Diagenesis

Quite commonly the matrix of the pisoliths is represented by coarsely crystalline calcite (5808, 2/4699, R35, R36, R964, R1208, R1211). Sometimes ghost outlines of replaced crystal fragments are recognisable in this (R964), but more frequently the calcite shows no sign of tuff structure. In R35 there are irregular patches of fine-grained tuff within the calcite.

Elongation ratios of 20 pisoliths each from two rocks with calcite matrixes (2/4699, R964) both gave averages of 1.08 (see above). Twenty pisoliths each from three rocks with tuff matrixes (R371, R1102, R1204) gave average elongation ratios of 1.40, 1.42, and 1.75. All pisoliths were measured on a vertical face perpendicular to the bedding. Although only five rocks were measured the measurements reflect what would be concluded from a subjective assessment of all the pisoliths: tuff with a calcite matrix have nearly round pisoliths, while tuffs with a tuff matrix have flattened pisoliths. Thus the calcite diagenesis which protected the enclosed pisoliths from deformation, took place at a very early stage in the compaction of the rocks.

"Pisoliths" in Agglomerate

The specimen R972, although listed above, was collected (by L. E. de la Hunty) from the Fortescue Group as conglomerate. It is an aggregate of subangular fragments of aphanitic tuff and altered lava mostly 10-15 mm across with much calcite replacement. A cut and smoothed face reveals that about 5 per cent. of the fragments are structureless whole spheroidal "balls" of fine-grained tuff. Although superficially resembling the pisoliths just described, they lack grading and concentric structure of any kind, and appear to represent reworked pieces of lithified tuff in a later agglomerate.

PUBLISHED ACCOUNTS OF PISOLITIC TUFF AND COMPARISON WITH WESTERN AUSTRALIAN EXAMPLES

Moore and Peck (1962) have described tuffs with accretionary lapilli (= pisolitic tuffs) of various ages in the western continental United States and have very thoroughly reviewed all previous relevant literature. The rocks described by Moore and Peck are so closely similar to the Western Australian tuffs as to leave no doubt that the two groups of rocks have the same origin. They list (p. 189) and give authorities for the three observed mechanisms of formation of volcanic pisoliths as follows: (1) accretion on the ground of fresh ash around a nucleus blown by the wind or rolling down a slope; (2) absorption by fresh ash of the water of a fallen raindrop during a light rain; and (3) accretion of moist ash in an eruptive cloud to form mud-pellet rains. They also note a fourth possible mechanism akin to that favoured by Hansen and others (1963) for pisolitic tuffs of the Oak Springs Formation in southern Nevada: (4) that the lapilli formed in water by the gentle agitation of a nucleus in contact with unconsolidated volcanic ash.

In spite of their close resemblance the pisolitic tuffs appear to differ from those described by Moore and Peck (1962) as well as those noted later by Sundelius (1963) in the following ways:

1. In the United States examples, the pisoliths occur in poorly stratified, probably terrestrial rocks (Moore and Peck, 1962, p. 184, 190, 191). Commonly the Fortescue Group tuffs are subaqueous rocks; this is clear from the nature of the stratification, the presence of dolomites with *Collenia* (Edgell, 1964) and the presence of ripple marks (Kriewaldt and Ryan, in press) and small-scale cross-bedding.

2. The United States pisoliths are not sorted (p. 190). Pisoliths of Fortescue Group specimens typically have a narrow size range.

3. Moore and Peck (p. 190) note the presence of broken pisoliths in all specimens. In the Fortescue Group rocks most specimens lack broken pisoliths.

PROBLEMS OF ORIGIN

Apart from the textural disqualifications listed by Moore and Peck (1962) of the first two genetic hypotheses, no origin involving rainfall on dry ash is easily acceptable for a pisolitic tuff stratigraphically consistent for more than 300 miles. Moore and Peck favour the third hypothesis. Although they cite two observed falls of tuff posilites it is a pity that there is no published evidence that the resultant tuffs resembled typical pisolitic tuffs in all minor textural details. There are a number of cogent objections to this hypothesis for the Fortescue Group pisolites:

1. The Fortescue Group tuffs are subaqueous rocks. It is difficult to believe that falling pisoliths would not only survive impact against water but also retain enough strength under immersion to keep their spherical shape as they fell and accumulated on the bottom.

2. The similarity between the tuff of pisolith and matrix is extremely close. It would be expected that aggregation of particles in a cloud would, at least sometimes, act as a mechanism for sorting airborne material, to give some observable difference in composition.

3. Typically, pisolitic tuff has closely packed pisoliths of even size in a tuff matrix in a homogeneous bed. It seems an extraordinary coincidence, if pisoliths and tuff fell together, that the supply of each was always just enough for the interstices of the pisoliths to be evenly filled by ash as they accumulated.

The following hypothesis, similar to Moore and Peck's fourth alternative, would not be faced with these objections. In certain subaqueous tuffs of critical limits of composition and grain-size distribution, there is soon after deposition a tendency for aggregation of the finer material towards evenly distributed centres whose average separation is controlled by the grain-size of the rock. Although no detailed explanation of the process is attempted here it is likened to the flocculation of colloids, which is simply an aggregation of fine particles. A coarse nucleus is not thought essential for the process, but represents a centre of attraction which happened to be occupied by coarse material. The process takes place within a few feet, or possibly a few inches, of the surface, since pisoliths may be exposed and broken or sorted by current winnowing. The finest outer shell acquires competence quickly and the gradual expulsion of water and compaction of each pisolith is associated with an inward extension of the hardening, and an increase in permeability of the matrix.

The hypothesis seems to fit certain features of the collection described which on other hypotheses are irrelevant or coincidental. In three of the current-modified rocks (2/4700, 2/4701, R1203) the pisoliths are of the type with fragile peripheral shells. These I suppose to be early-formed types, which are most likely to be uncovered and sorted. From the manner of their breaking it is clear that this type has a soft plastic core. The extreme similarity between pisolith and matrix is explained, as is the lack of size range and the close, even distribution. On this hypothesis I interpret the graded bed of R1208 as an originally non-pisolitic graded tuff in which pisolith size was controlled by grain-size. It is easy too, to see the common development of interstitial calcite as a natural result of the increase of permeability in, and withdrawal of fine material from, the matrix.

The differences noted above between the pisolite tuffs described here and those described by Moore and Peck suggest that the common rock of the Fortescue Group, with even-sized, spheroidal, close-packed, whole pisoliths, is the first result of internal development, by flocculation, of pisoliths; and that the variants with broken, scattered and sorted pisoliths, which have been described from the United States and which occur less abundantly in the Fortescue Group, are later modifications of such rocks. This process of flocculation is not, of necessity, an observable phenomenon, but, until it is shown that mud-pellets of the type which have been seen to fall to form rocks resembling the pisolitic tuffs described here in all textural details, the flocculation hypothesis seems to have more advantages than disadvantages as a genetic hypothesis.

CONCLUSIONS

Pisolitic tuffs, though never abundant, are widespread in space and time. No hypothesis for their origin either satisfactorily explains all the observed characters of the rocks or has sufficient supporting evidence to prove its truth beyond reasonable doubt. Fortunately it is easy to see what further evidence should be sought. Some priorities are:

1. What is the detailed geometry of individual pisolitic tuff beds? The greater their lateral persistence the weaker the case for falling mud pellets.

2. Do the pisoliths which have been observed to fall from dust charged clouds near volcanic eruptions correspond in detail, or result in deposits which correspond in detail, to pisolitic tuffs of the commonest type?

3. How do grain-size distribution analyses of pisolitic and non-pisolitic tuffs compare? They should be very close if pisolith formation is simply a colloidal flocculation. They may be close on a falling mud pellet hypothesis but should sometimes differ.

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PROGRESS REPORT ON THE BROCKMAN IRON FORMATION IN THE WITTENOOM—YAMPIRE AREA

By A. F. Trendall

ABSTRACT

The Precambrian Brockman Iron Formation, of the North-West Division of Western Australia, is 2,200 feet thick in the central part of its outcrop, which is 300 miles long and 100 miles across. Drilling through the lowermost 600 feet of the unmetamorphosed, unoxidised and undisturbed formation in the Wittenoom-Yampire area has yielded 6,250 feet of core from 27 holes separated over a maximum distance of 15 miles. These samples reveal that between 100 and 460 feet above the base there is a regular alternation of "shale" (mainly shale but with some chert and carbonate) bands 1-20 feet thick and bands of banded iron formation (b.i.f.) 8-28 feet thick, with the b.i.f./"shale" ratio over the whole thickness close to 2.0. These major bands are called *macrobands*; thinner alternations of chert, magnetite, etc., within the b.i.f. are called *mesobands*, while fine even laminations of quartz and carbonate within chert mesobands are called *microbands*. Lateral correlation between all holes is effectively perfect at mesoband and larger scales. Thickness variations are small and have no simple regional pattern. Near the top and bottom of the specific 360-foot thickness already referred to, abundant massive blue (mass-fibre) riebeckite mesobands over thicknesses of about 40 feet define upper and lower *riebeckite zones*. Two main *seams* of blue asbestos (crocidolite; cross-fibre), in which a few mesobands of fibrous riebeckite may be mined together, are associated with the lower riebeckite zone. In this zone there is no correlation between total riebeckite content and either stratigraphic thickness or fibre thickness, and the riebeckite has no simple regional distribution. Massive riebeckite mesobands result from metasomatic replacement of particular ("riebeckite-prone") cherts at a restricted number of levels in an erratic manner. The specific gravity of the b.i.f. varies between 3.36 and 3.39 and the bulk mineral composition by weight is approximately:

	Per Cent.
Quartz	45
Magnetite	30
Carbonate	15
Stilpnomelane	8
Others	2

"Others" include riebeckite and other amphiboles, hematite, pyrite, apatite, other phyllosilicates, and feldspar. Three main mesoband types, chert, quartz-iron oxide (QIO), and magnetite, constitute about 90% of the total b.i.f. From the evidence of microbanding there is a gradation from "primitive chert" with coarse microbanding either into "flat-modified" chert with fine microbanding or into chert pods within QIO; this is thought to reflect two types of diagenetic modification of an original microbanded material whose exact nature is not known. If microbanding results from annual changes in geochemistry of depositional environment an acceptable depositional rate of one foot of compacted b.i.f. every 2,000 years is arrived at.

INTRODUCTION

Objectives

Diamond drill cores recovered by the Australian Blue Asbestos Co. (A.B.A.) during an exploratory drilling programme in this area, started in 1961, represent samples of unoxidised unmetamorphosed and undistorted Precambrian iron formation unique in the degree to which all three qualities are developed together. The main objective of this report is to begin an assessment of the geological significance of this drilling, particularly insofar as it contributes to the solution of the three problems:

(1) What is the origin of banded iron formations?

(2) What is the origin of riebeckite within these?

(3) What is the origin of the fibrous riebeckite (crocidolite) in riebeckite-bearing iron formations?

The Brockman Iron Formation, from which these cores were derived, is of great economic interest both for iron and asbestos, and this report represents an early stage in a continuing study of the formation.

Regional Geological Environment

The Brockman Iron Formation (MacLeod and others, 1963) crops out over an area of the North-West Division about 300 miles long in an east-southeast direction and 100 miles across in a north-northeast direction. It is a formation of the Hamersley Group, from which acid volcanics have been dated at 2,100 m.y. (Leggo and others, 1965), and is 2,200 feet thick in the central part of its outcrop. It is underlain conformably by nearly 20,000 feet of iron formation, dolomite, shale, sandstone and mixed volcanics of the Hamersley and Fortescue Groups and is overlain conformably by 15,000 feet of similar rocks, but with a higher proportion of clastic sediments, of the Hamersley and Wyloo Groups. In the northern part of its outcrop, along the Hamersley Range, dips are generally less than 5°, although local puckers cause abrupt but confined steepening. Unfortunately, much of the upper part of the formation has been removed. Between about 80 and 150 feet above the top of the underlying Mt. McRae Shale, bands of riebeckite asbestos are mined by the Australian Blue Asbestos Co. at Colonial Mine, Wittenoom Gorge. Mining was formerly carried on at about the same stratigraphic level at Yampire Gorge, 13 miles to the east. It is in both these areas, in the effectively undisturbed lower part of the formation, that the drilling programme was, and is being, conducted.

The Drilling Programme

Between 1961 and September 1964, forty-four holes were drilled. Until 1963 drilling techniques were variable and a number of technical difficulties which led to erratic core recovery had to be overcome. Specially designed bits were later used and a system developed whereby a down-the-hole hammer was used until it became easier to core. Coring was then carried out until the lowest mined asbestos had been passed. Thus cores start at a variety of stratigraphic levels (see Plate 32) but all finish at about the same horizon. Recovery is virtually 100% in the later holes.

Most of the holes were drilled just to the north, west and south of the existing mine, and would be included in a circle of radius 1 mile centred on the western part of the mine area. Exceptions are: Hole 47, about 4½ miles west-southwest of the mine; Hole 46, about 3 miles west of the mine; Holes 67-81, extending about 2 miles southwest along Wittenoom Gorge; and Holes Y1 and Y3 at Yampire Gorge, 13 miles to the east.

These localities are only given roughly since, as noted below, they are not significant for this report.

Material Available

In September, 1964 about 6,250 feet of core from 27 holes was available for study, individual holes varying from 630 feet (63) to 52 feet (59) in length of core. The core from most of the earlier holes is too disordered to be of correlative use, and even in the later holes gaps exist (largely due to removal of this highly decorative core) which, as noted below, may affect some of the results recorded. A.B.A. has kindly supplied graphic logs of 24 holes, asbestos assay values of 33 holes, and grid localities of all sites. The complete core of Hole 51 (314 feet) has been transferred to the Geological Survey for permanent record and reference.

Plan and Progress of Work

I visited Wittenoom briefly in August, 1963 and was impressed by the unique opportunities presented by the A.B.A. core for obtaining precise information on the lateral persistence of "bands" in "banded iron formation" at a range of scales, apart from its obvious value as a stratigraphically continuous unweathered sample of part of the Brockman Iron Formation. I collected approximately 6 feet of stratigraphically equivalent core (Plate 32) from Holes 28, 33 and 46, and three feet equivalent to the lower part of this from Hole 40. By July, 1964 over a hundred thin sections had been cut and the small-scale lateral continuity had been studied. Petrologist's Report No. 66 (unpublished) summarised petrographic results of this work.

In cooperation with A.B.A. the Geological Survey of Western Australia initiated a special study of the asbestos in 1964, with G. R. Ryan in charge, and in September, 1964 I spent a further 14 days at Wittenoom concentrating on riebeckite and crocidolite.

With well over a mile of core, the first problem becomes one of deciding what information to select. Since large-scale graphic logs existed I logged at Wittenoom:

1. A specific stratigraphic level about 45 feet thick at a smaller scale (the "lower riebeckite zone"—see below).

2. A level within this about 3 feet thick at a smaller scale (1:1).

3. The upper mined asbestos seam, also within the 45 feet of "1" above.

Apart from the common sense of studying a successively smaller sample in increasing detail the particular sections logged were chosen to bear largely on the origins of riebeckite and crocidolite. About 12 feet of core was taken for laboratory study.

NOMENCLATURE OF THE MAIN ROCK-TYPES

"Shale" and Banded Iron Formation

The Brockman Iron Formation contains these two rock-types in alternating bands; brief descriptions of each follow:

The *banded iron formation* (abbreviated to *b.i.f.* in much of this report) has a specific gravity varying between 3.36 and 3.39, and although a programme of properly sampled chemical analysis is not yet completed the following estimate of mineral content (by weight) is probably not much in error:

Quartz 45%
Magnetite 30%
Carbonate 15%
Stilpnomelane 8%
Others 2%.

The "others", in probable order of abundance, are riebeckite (all textural varieties), hematite, pyrite, apatite, other amphiboles and phyllosilicates, and feldspar. The carbonates include siderite, ankerite, ferroandolomite and calcite. The rock is hard, compact and has a conspicuous and even banding on a range of scales caused by the concentration of the principal minerals into layers in which one or other is dominant.

The separation into "shale" and banded iron formation is a clear and consistent one. Although the change from one rock-type to the other may take place gradationally over a few feet at the edges of the thicker bands, in the thinner "shales" the edges are sharply definable. Within the "shales", although lithology is variable, there is no tendency for confusion with or gradation into banded iron formation. The term "shale" is used within quotation marks because it is used for convenience to cover a number of differing types. The bulk of the material is very fine-grained, black, green, grey or brown shale which may be highly fissile along the bedding or almost massive. Similarly there may be conspicuous fine colour banding. The chemical analyses available suggest that this wide range of types reflects a correspondingly wide range in mineral composition, and a variety of iron-rich phyllosilicates are probably the chief constituents. An X-ray study of these shales is planned. The green shale grades into tough green carbonate which in core is difficult to distinguish from massive shale. (At the surface the dolomite is yellow-weathering). White chert bands, mostly 1-2 inches thick, sharply divided from the dark shales, are common and vary in abundance. Thus "shale" refers to "shale with subordinate cherts and carbonate".

The sharply defined base of a breccia with angular shale and chert fragments up to several feet long, lies between 2 and 10 feet above the base of the fourth "shale", or Calamina Member (see "Stratigraphy" below). The breccia usually grades into shale over about 3 feet, with one or two thinner graded beds following it before undisturbed shale finally appears. In the seventh "shale" angular pieces of shale and other material about an inch across occur over about 3 feet without obvious grading. At both levels white-rimmed spheroidal bodies about a millimetre across are present in the breccia. These breccia bands are the only sign of irregularity of stratification throughout the part of the Brockman Iron Formation studied. No detailed work has yet been carried out on them and they are not reported on further here.

Miscellaneous Definitions

It is convenient to define terms for the three main scales on which the Brockman Iron Formation may be described as "banded". These are:

1. Gross variations in lithology from "shale" to banded iron formation.

2. Banding defined by changes from "chert" to "carbonate" or "magnetite" within the banded iron formation proper and which are internally consistent and which are named after the predominant mineral of the band. Such bands are typically ¼ inch to 1 inch thick.

3. Fine banding within individual cherts of scale 2 above. It appears as a rhythmic alternation of stripes usually richer or poorer in carbonate or stilpnomelane and usually has between 2 and 5 (double) stripes to a millimetre.

For convenience I propose to refer to these three scales as "macrobanding", "mesobanding" and "microbanding", and to the bands themselves as "macrobands", "mesobands" and "microbands". Thus a chert mesoband may have internal microbands and be part of a macroband. The term "band" used alone may refer to any of these three types but is only used in a context where the meaning is apparent. Other types and scales of banding are present, and are noted below, but are of minor importance.

The term *chert* in this report denotes a rock with a matrix of finely crystalline (almost invariably in the range 5-30μ) quartz. Cherts of iron formation are so different from normal sedimentary or metamorphic quartzite that the term seems preferable.

The term *riebeckite* is applied at Wittenoom to massive blue mesobands made up of randomly interlocking riebeckite needles. Such bands are referred to in South Africa as *mass-fibre* bands.

The term *fibre* is applied at Wittenoom to mesobands of fibrous riebeckite with a common orientation nearly normal to the stratification. *Crocidolite, cross-fibre* or *blue asbestos* are synonyms.

A single mesoband of crocidolite is referred to as a *band*, or mesoband. A group of bands that can be mined together constitute a *seam*. A riebeckite-bearing stratigraphic thickness with which a seam or seams may be associated is called a *riebeckite zone*. These terms have the following equivalence with those in use in South Africa (Cilliers, 1961, p. 28):

South Africa	Western Australia
seam or band	band or mesoband
reef	seam
horizon	riebeckite zone

A Western Australian riebeckite zone is not the precise equivalent of the South African asbestos horizon, since one is defined by riebeckite and the other by asbestos. This is more of a geological accident than an indication of fundamental differences in the two; both terms denote a stratigraphic thickness in which riebeckite (*sensu lato*) is exceptionally abundant.

In South Africa (Cilliers, 1961, p. 16) "zone" is used as a major stratigraphic unit in a manner which would not be admissible under the Australian Code of Stratigraphic Nomenclature. It would be the equivalent of either a Formation or a Group. It is also used in South Africa with reference to weathering.

STRATIGRAPHY

General

A vertical section of the lowermost 750 feet of the Brockman Iron Formation in the Wittenoom-Yampire area, constructed solely from borehole information, is shown in the right hand column of Plate 32. The salient features are:

1. An alternation of banded iron formation and "shale" macrobands, two of which have the status of members.

2. Two riebeckite zones with centres roughly 150 feet and 450 feet above the base.

3. Three main fibre seams below the lower riebeckite zone. The upper and lower fibre seams are those currently mined at the Colonial Mine.

This section was constructed as follows: From the base to the shale below the lower fibre seam information is entirely from Y1, the only hole to penetrate to the Mt. McRae Shale. The boundary between the two formations is transitional, and the base of the Brockman Iron Formation will be defined later within the range shown on Plate 32. Where the base is referred to above it means the lowest possible position. From this shale upwards for about 366 feet the macrobands shown have the mean thicknesses of a number of holes. These thicknesses, together with the range of thickness and the number of holes used to determine the mean, are shown in the table to the right of the column. Each "shale" and b.i.f. macroband is numbered for subsequent reference. Above "shale" 16 information is solely from Hole 63.

Nomenclature

Two local names are to be formally defined by G. R. Ryan and are for field use on a regional scale. The Calamina Member is the fourth "shale" macroband and the Joffre Member is the fifteenth "shale" macroband of this report (Plate 32). Other equivalences between the nomenclature of this report and that of A. B. A. geologists at various times are:

This report	Local Wittenoom usage
Third fibre seam	Knapping seam
No equivalent term	Knapping seam marker
First " shale "	Lower seam marker
Second " shale "	Upper seam marker
Upper riebeckite zone	Upper Yampire Zone Upper Yampire Series
Lower riebeckite zone	Yampire Zone Yampire Series

Lateral Correlation

Good lateral correlation at the macroband scale is evident from a glance at the A.B.A. graphic logs.* In the core from below the third "shale" and in the true-scale logs from a selected level within the lower riebeckite zone (see "Plan and Progress of Work") there is spectacular continuity on the mesoband scale, to an extent that unlabelled vertically sawn half-cores at the same stratigraphic level from different holes could be accepted as coming from a single hole. Briefer examinations at other levels show that lateral continuity at mesoband scale is, within the greatest distance between two cored holes (15 miles), effectively perfect, and that in the whole 366 feet of the central part of the right-hand column of Plate 32, of which a number of cores are available, no discontinuity of mesobanding (apart from the "podding" mentioned later) exists in the banded iron formation parts. Although no close study has been made of the cherts within "shales" my impression is that their continuity is much less perfect.

On a wider scale, a single chert mesoband about an inch thick within the Mt. Sylvia Iron Formation and some 400 feet below the base of the Brockman Iron Formation, has been observed to be stratigraphically continuous for at least 150 miles along the northern face of the Hamersley Range.

Thickness Variations (large-scale)

The table in Plate 32 shows that the part of the Brockman Iron Formation between about 100 feet and 466 feet above the base, from the base of the first "shale" to the top of the sixteenth "shale," has a mean thickness of 366.4 feet. Of this thickness 107.5 feet (or 29.3%) consists of "shale" in sixteen macrobands of mean average thickness 6.7 feet, and 258.9 feet (or 70.7%) is banded iron formation in 15 macrobands, alternating with the "shales," of mean average thickness 17.3 feet.

To study thickness variation between and within holes this part of the formation was divided into 15 *sections* between "shale" centres. The lower 11 of these sections, between the centres of the first and twelfth "shales" are common to 12 holes and for statistical uniformity attention is mainly confined to these in this report.

The mean total thickness of sections 1-11 for all 12 holes is 249.1 feet, with a range of individual values from 233 feet (or —6.5% of the mean; Hole 40) to 258 feet (or +3.6% of the mean; Hole 33). In all 12 holes there is thus an extreme thickness range of 25 feet, or 10.1% of the mean. The mean deviation is 2.5%. Regarding each drill core as a local sample of stratigraphic thickness, three main questions arise from these figures:

1. Does the regional distribution of thickness allow the construction of a simple isopach pattern?

2. In a thick† hole is the thickness evenly distributed internally?

3. Is the thickness variation mainly due to variations in the thickness of the constituent "shales", or of banded iron formation macrobands, or to both?

The answers to these questions, numbered as above, are:

*The nomenclature of rock-types in these logs differs slightly from that used here; these differences are not important, and are not referred to again.

†*thick* and *thin* holes or sections refer to holes or sections whose thickness is above or below the mean for all holes.

1. No simple isopach pattern fits the areal thickness distribution. In some instances (Holes 67, 68, 69) a group of close holes shows a thickness range little short of the total range. It is certain that any major regional variation in thickness over the Wittenoom-Yampire area is so effectively hidden by minor local fluctuations that an impossibly close pattern of sampling would be necessary to detect it.

2. This is a more difficult question. In Table 1 are shown, for the 12 holes used for thickness study, the number of separate sections less than, greater than, or equal to the mean for that section, and the terminal* deviation of the total from the mean at that level. In a general way the terminal thickness of any hole is a reflection of the number of sections above and below the mean thickness of each section. Some interesting exceptions to this are: Hole 33, which in spite of a terminal percentage of 2.7 above the mean has as many constituent sections at or below the mean as it has above; and Hole 29, which has the same distribution of sections above and below the mean as Hole 33, but has a terminal thickness below the mean.

Table 1

SUMMARY OR INTERNAL THICKNESS DISTRIBUTION IN 12 HOLES

1	2	3	4	5	6
Hole No.	Number of Sections				Terminal Per cent. Deviation from Mean
	Above Mean	Below Mean	At Mean	Total	
33	7	6	1	14	+2·7
75	6	4	1	11	+2·8
49	10	5	0	15	+2·3
27	8	5	0	13	+2·1
28	6	6	0	12	+1·4
51	6	7	0	13	—0·2
62	7	6	0	13	+0·1
29	7	6	0	13	—0·5
61	6	8	1	15	—0·5
63	6	8	1	15	—1·9
46	3	10	0	13	—4·0
40	2	9	1	12	—5·4

There is no regular alternation or grouping in the holes of sections above and below the sectional means. Of 147 sectional contacts in this study 81 show a change (i.e. below the sectional mean to above it, or vice versa) and 66 show no change. The equivalent percentages, 55 and 45, show that the chances are very nearly equal that a section thicker than the sectional mean will be succeeded, or underlain, by a section above or below its sectional mean.

At present it seems that the gross variations in thickness between holes can be accounted for entirely by a random stacking of thick and thin sections, a thick hole being the result of a fortuitous succession of thick sections, and vice versa. The sedimentational significance of this is that each section, considered as a sedimentary unit, varies areally in thickness in a way unrelated to preceding sections. No simple regional pattern should be produced and it has been seen that this is so.

It is assumed here that the present thicknesses of the rocks are directly related to the original thicknesses of deposited material. It will be shown later that extreme compaction has probably taken place, and it may be that present thicknesses are controlled more by compaction than by deposition. This is a problem for future attention.

3. It is theoretically possible for the thickness variations discussed to be controlled mainly or entirely by either one of the two macroband types involved in each section ("shale" or banded iron formation) or to be contributed to by both types equally. In Table 2 are shown, over the range of the 11 lowermost sections only ("shales" 1-12), for the 12 holes used in Table 1, the total thickness (column 2), the "shale" and b.i.f. thickness (columns 3-6), and the ratio of b.i.f. to "shale".

*terminal here means at the top of the highest section in the hole measured upwards from the centre of the first "shale."

It is clear from this table that the relationship between total thickness and "shale" thickness is highly erratic.

Although the upper six (thickest) holes have a mean total thickness of 255 feet and a mean "shale" thickness of 83 feet, and while the lower six (thinnest) holes have equivalent thicknesses of 243 feet and 88 feet (in other words greater thickness, less "shale") the variation within these two groups is so great (e.g. the thinnest hole has the least "shale") that it is of doubtful significance. On this point one can only say that although there is some suggestion that hole thicknesses are related more to constituent b.i.f. thicknesses than to "shale" thicknesses, more information is needed on the precise correlation of "shale"/b.i.f. boundaries. It may be that logging inconsistencies contribute largely to the confusion.

Table 2

SUMMARY OF THE CONTRIBUTION TO TOTAL THICKNESS VARIATION OF "SHALE" AND BANDED IRON FORMATION

1	2	3	4	5	6	7
Hole No.	THICKNESS					Ratio B.I.F. " Shale "
	Total (feet)	" Shale "		B.I.F.		
		Feet	Per cent.	Feet	Per cent.	
33	258	87	34	171	66	2·0
75	256	93	36	163	64	1·8
49	256	88	34	168	66	1·9
27	255	73	29	182	71	2·5
28	252	82	33	170	67	2·1
51	252	73	29	179	71	2·5
62	250	89	36	161	64	1·8
29	248	86	35	162	65	1·9
61	248	95	38	153	62	1·6
63	243	90	37	153	63	1·7
46	238	87	37	151	63	1·7
40	233	69	30	164	70	2·4

Thickness Variation (small-scale)

It is clear from the preceding discussion that sample-size is vitally important in studying thickness variation. It is not yet known, for example, what relationship the thickness of the studied (mean) 249.1 feet has to the total thickness of the Brockman Iron Formation at the site of each hole; that is, whether a 250 foot sample of a 2,000 foot formation is an adequate one. On a smaller scale it is clear that a single section has no value as an index of the thickness of all 11 sections between the first and twelfth "shales" in any hole. Three further questions now arise:

1. What is the relationship between sample-size and variability from hole to hole?

2. What is the least thickness that will give a reasonably reliable indication of gross thickness?

3. Do either "shale" or b.i.f. macrobands tend to be more consistent internally than the other?

These questions can be less reliably answered than the preceding three. In Table 3, in which all the figures relate to the 12 holes of Tables 1 and 2, the mean values of each section and their mean deviations are given (columns 2 and 3) together with the corresponding cumulative figures for successively larger groups of sections from the first "shale" upwards. The mean of column 3 is 5.8; from this and from the upward diminution of values in column 6 it is clear that smaller samples show a higher percentage mean deviation. The values in columns 2 and 3, and of columns 5 and 6 are plotted against each other in Figure 1, in which the smoothed (exponential) curve suggests that a sample of 100 feet gives a mean deviation little higher than a sample of 250 feet. Ideally, all possible combinations of sections should be included on this figure, and standard deviations would be preferable to mean deviations (here and elsewhere in this paper) but time and equipment have not been available for these calculations.

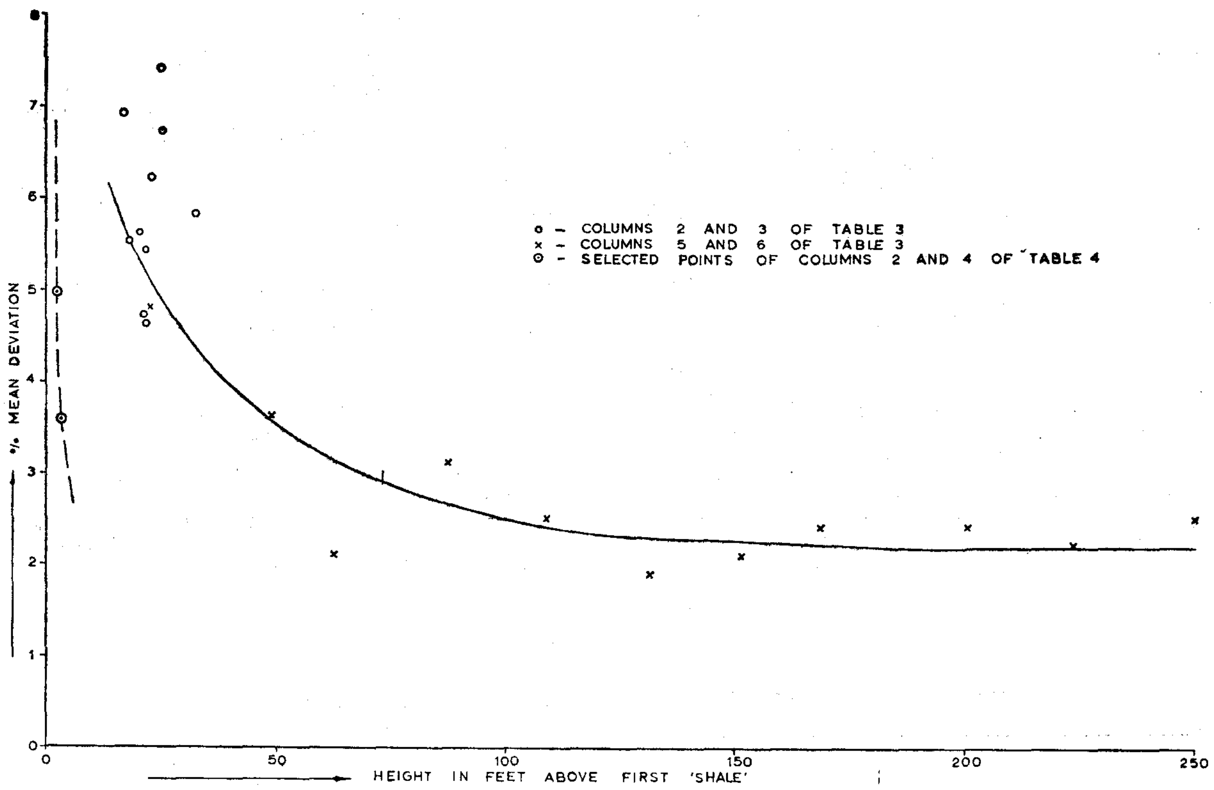


Figure 1—Graph relating mean deviation and stratigraphic sample thickness in the lower part of the Brockman Iron Formation in the Wittenoom-Yampire area.

At a smaller scale the true-scale logging of about 3 feet from within the second b.i.f. macroband (see "Plan and Progress of Work" above) provides further data. In this thickness 35 easily correlatable exact levels (mesoband boundaries) were marked and measured. In general, levels 1-16 (from the top down) are free of riebeckite and occupy about 17 inches, levels 16-24 occupy about 10 inches, of which about half is riebeckite, and levels 24-35 are free of riebeckite and occupy 11 inches. Exact means, with the number of holes used and mean deviations are given for the whole and different parts of this thickness in Table 4.

Table 3

VARIATION OF MEAN DEVIATION WITH SIZE OF STRATIGRAPHIC SAMPLE

1	2	3	4	5	6
Separate Sections			Cumulative Figures from the Bottom Upwards		
Section	Mean Thickness (feet)	Mean Deviation Per cent.	Section	Mean Thickness (feet)	Mean Deviation Per cent.
"Shales" 11–12	25·6	6·7	"Shales" 1–12	249·1	2·5
"Shales" 10–11	23·1	6·2	"Shales" 1–11	223·5	2·2
"Shales" 9–10	32·1	5·8	"Shales" 1–10	200·4	2·4
"Shales" 8– 9	17·0	6·9	"Shales" 1– 9	168·3	2·4
"Shales" 7– 8	20·1	5·6	"Shales" 1– 8	151·3	2·1
"Shales" 6– 7	21·9	5·4	"Shales" 1– 7	131·2	1·9
"Shales" 5– 6	21·7	4·7	"Shales" 1– 6	109·3	2·5
"Shales" 4– 5	24·8	7·4	"Shales" 1– 5	87·6	3·1
"Shales" 3– 4	21·9	4·6	"Shales" 1– 4	62·8	2·1
"Shales" 2– 3	18·4	5·5	"Shales" 1– 3	40·9	3·6
"Shales" 1– 2	22·5	4·8	"Shales" 1– 2	22·5	4·8

Table 4

VARIATION OF MEAN DEVIATION WITH THICKNESS OF SAMPLE WITHIN BANDED IRON FORMATION

1	2	3	4
Stratigraphic Thickness	Mean Thickness (inches)	Number of Holes	Mean Deviation Per cent.
Levels 1–35	37·52	18	3·57
Levels 1–16	16·93	20	4·84
Levels 16–24	9·64	21	7·05
Levels 24–35	10·88	21	5·24
Levels 1–16 and 24–35 (all riebeckite-free)	27·74	19	4·94
Levels 15–16 (one mesoband)	0·70	22	24
Levels 24–25 (one mesoband)	0·54	22	39

Two points from this table are included on Figure 1: that for levels 1 to 35 (the lower one on the graph) and that for (1 to 16) + (24 to 35). The measurements show that the 3 feet of b.i.f. chosen has a percentage mean deviation through all the available holes equivalent to that of a 20-30 foot stratigraphic sample which includes shales.

From the data presented the following answers can now be suggested for the questions above:

1. As the sample size decreases from 250 feet the mean deviation shows little change until about 100 feet, after which it increases rapidly.

2. About 100 feet, or any five sections, will give an index of thickness that will be little improved by greater measurement.

3. Within b.i.f. there is greater lateral consistency of thickness than in sections which include b.i.f. and shale.

A test of correlation between the logged 3 feet of the second b.i.f. macroband and the total thickness of the macroband would be interesting but the graphic logs are not reliable to a greater accuracy than whole feet, and this is insufficient for the purpose.

Rhythmic Sedimentation

From Plate 32 and from the sectional thicknesses given in Table 3, it is apparent that the Brockman Iron Formation has a strikingly regular alternation of "shale" and banded iron formation. The average mean sectional thickness (15 sections) is 24.0 feet, with a range of 17.0 to 32.1 feet.

If it be supposed, as a working hypothesis, that a neighbouring "shale"/b.i.f. macroband pair constitutes a unit of cyclic sedimentation then either the "shale" above or below could be combined with each b.i.f. to comprise such a unit. If it is then supposed that units have constant thickness two results would be expected: the proper combination would show a smaller total range of thickness and each individual unit would vary less between holes. In Table 5 the mean thicknesses, range and limits, and standard deviations (numerical and as percentage of mean) are given for b.i.f. macrobands with their underlying "shales" (columns 1-5) and for the same b.i.fs. and their overlying "shales" (columns 6-10). The mean of column 2 is 22.6 feet, with a range of 13.6 to 32.2 feet while the mean of column 7 is 22.8 feet, with a range of 15.7 to 30.7 feet. The means of columns 5 and 10 are 10.5 and 7.5 respectively.

Thus, if the original postulates are valid, there is an indication that the combination of a b.i.f. macroband with its overlying "shale" macroband is more properly regarded as a complete sedimentary entity than the combination with the underlying "shale". The principal importance of this hypothesis is that it could provide a clue to the origin of iron formation, in that the deposition of a "shale" is a natural consequence of iron formation deposition rather than vice versa. The hypothesis also indicates that the most likely places for breaks in sedimentation to be sought are at the tops of "shales" rather than the bottoms. A comparative study of "shale"/b.i.f. transitions above and below "shales" should be undertaken on the A. B. A. cores.

Just above the twelfth "shale" macroband there is a remarkably regular alternation of chert mesobands about 5 inches thick separated by softer (QIO, see below) mesobands about 2 inches thick. There are at least nine alternations here, so regular as to be immediately recognisable in the cliffs. This is an exceptional type of rhythmic regularity which has not been seen elsewhere.

Table 5

SUMMARY OF TWO POSSIBLE MODELS OF RHYTHMIC SEDIMENTATION

1	2	3	4	5	6	7	8	9	10
Combinations of Banded Iron Formations with Underlying Shales					Combinations of Banded Iron Formations with Overlying Shales				
"Shale" + B.I.F. No. No.	Mean Thickness (12 Holes) (feet)	Range and Limits (feet)	Standard Deviation: Numerical Value	Standard Deviation: %	"Shale" + B.I.F. No. No.	Mean Thickness (12 Holes) (feet)	Range and Limits (feet)	Standard Deviation: Numerical Value	Standard Deviation: %
11 + 11	32·2	23–35(12)	3·2	9·9	12 + 11	18·8	16–21 (5)	1·6	8·5
10 + 10	19·8	15–29 (14)	3·6	18·2	11 + 10	27·4	25–29 (4)	1·3	4·7
9 + 9	34·4	27–40 (13)	3·8	11·1	10 + 9	30·4	29–32 (3)	0·9	3·0
8 + 8	13·6	10–17 (7)	2·3	16·9	9 + 8	20·6	16–26 (10)	2·5	12·1
7 + 7	20·7	18–22 (4)	1·4	6·8	8 + 7	19·3	16–23 (7)	1·7	8·8
6 + 6	29·0	27–32 (5)	1·3	4·5	7 + 6	15·7	13–18 (5)	1·6	10·2
5 + 5	12·7	10–15 (5)	1·3	10·2	6 + 5	30·7	28–34 (6)	1·7	5·7
4 + 4	29·0	26–32 (6)	2·1	7·2	5 + 4	20·3	17–22 (5)	1·5	7·5
3 + 3	17·4	15–22 (7)	1·8	10·3	4 + 3	25·7	24–29 (5)	1·5	5·8
2 + 2	18·7	16–21 (5)	1·4	7·5	3 + 2	18·7	14–20 (6)	1·7	9·1
1 + 1	22·3	20–25 (5)	1·7	13·1	2 + 1	22·7	20–27 (7)	1·8	7·9

The Lower Riebeckite Zone

The A. B. A. graphic logs, at a scale of 10 feet to an inch, show clearly that a lower riebeckite zone, in which massive blue riebeckite mesobands are concentrated, is almost entirely confined between the second and fourth "shales"; in only a few holes do riebeckite bands occur outside these limits. On the other hand these large-scale logs seemed to show little regularity in the distribution of riebeckite within these limits and negligible correlation of riebeckite bands. In 18 holes the lower riebeckite zone was therefore re-examined and logged for graphic representation at a scale of 1.8 feet to an inch. In view of the known excellence of mesoband correlation the principal questions which it was hoped to answer by this, apart from the simple estimation of mean riebeckite content (Plate 32; left hand column) were:

1. Can riebeckite mesobands be correlated between holes?

2. If they can be correlated, and if a band is absent from a particular hole, is it represented by a break in mesoband sequence or by some other mesoband type?

3. Does there tend to be a constant total amount of riebeckite in any one hole, but unevenly distributed between the upper and lower parts of the zone (above and below the third "shale"), or is a small amount of riebeckite in the lower part of the zone usually associated with a small amount in the upper part?

4. Is there any simple areal pattern in the distribution of riebeckite?

5. Is there any correlation between riebeckite thickness and stratigraphic thickness of the third and fourth banded iron formation macrobands?

All these questions were answered. The answers are given below, numbered as above, with a brief summary of the data where appropriate:

1. After logging of the riebeckite mesobands and the marginal and central "shales" of the riebeckite zones the logs were arranged side-by-side using the third "shale" as a datum. The scales of plotting of the banded iron formation macroband above and below were adjusted for variations in stratigraphic thickness. From the resultant plot it was apparent that the development of massive riebeckite mesobands was confined to 15 main levels and the mean thickness of massive riebeckite mesoband was close to 3 inches. To give a more objective assessment of the distribution a vertical histogram was constructed summarising the total riebeckite content at successive small vertical intervals of the zone. The irregular appearance of the large-scale logs is due to a haphazard distribution of the riebeckite between these principal 15 available levels. These are shown on Plate 32, together with the mean and ranges (inches of riebeckite) for the two parts and the whole of the lower riebeckite zone. Some of these levels are more persistent than others, notably the lower three in both the upper and lower banded iron formation macrobands, but no absolute rules can be deduced for the preferred order of appearance of riebeckite in them. It must be emphasised that these massive riebeckite bands represent the bulk of the riebeckite in the zone, although no thin section from within the zone would lack a few hairs of amphibole.

Summarising the answer to the first question: the riebeckite mesobands in which the bulk of the riebeckite of the lower riebeckite zone is concentrated are confined to 15 main levels within the zone, and are easily correlatable between holes.

2. If there is no riebeckite at a potential riebeckite level it is invariably represented by a chert mesoband, usually 2-3 inches thick, of flat-modified type (see "Petrography" below). G. R. Ryan has suggested the name "riebeckite-prone" cherts for these.

3. There is no significant correlation between riebeckite content above and below the third "shale." Table 6 shows that a hole with little riebeckite below the "shale" may have abundant riebeckite above and vice versa; or there may be abundant riebeckite above as well as below, or only a little. From the means of Plate 32 the upper part of the zone has 14.1% of riebeckite while the lower has 9.1% but the erratic nature of the distribution is shown by the fact that in several holes there is more riebeckite below than above.

4. There is no simple areal pattern in the distribution of riebeckite. Closely spaced holes vary widely in riebeckite content.

5. There is no correlation between rieckbite content and stratigraphic thickness.

Table 6
RIEBECKITE CONTENT OF THE LOWER RIEBECKITE ZONE*

1	2	3	4
Hole No.	Riebeckite Thickness (inches)		
	Above Third "Shale"	Below Third "Shale"	Total
22	23·5	10·0	33·5
27	22·5	19·0	41·5
28	24·5	29·5	54·0
33	32·5	19·5	52·0
34	18·5	25·0	43·5
40	27·5	0·0	27·5
46	27·5	16·5	44·0
49	37·5	42·5	79·5
59	Incomplete	9·0	Incomplete
60	26·5	8·5	35·0
61	23·0	39·5	62·5
62	20·0	6·0	26·0
67	41·5	21·5	63·0
68	16·0	19·0	35·0
69	14·0	12·0	26·0
73	26·5	10·5	37·0
75	41·0	19·0	60·0
81	29·0	26·0	55·0

*The thicknesses in columns 2, 3 and 4 were obtained by adding together the thicknesses of massive mass blue riebeckite mesobands and adding on half the thicknesses of mesobands partially replaced by riebeckite. The resultant figures, while giving a reasonably accurate comparison between the holes, probably give generally high estimates for the absolute quantities of riebeckite present.

There is ample petrographic evidence that massive riebeckite bands result from the late metasomatic volume-for-volume replacement of a limited number of "riebeckite-prone" cherts within the riebeckite zone. Where an unreplaced riebeckite-prone chert is represented in another hole by a riebeckite band the latter is usually thicker than the equivalent chert. This is partly because the replacement extends up and down into neighbouring mesobands. The replacement usually extends further below the chert than above it. It is possible also that thicker cherts were more liable to replacement, but more evidence is needed here. Replacement of any or all of the 15 main riebeckite-prone cherts of the lower riebeckite zone appears to have taken place in a haphazard manner with no obvious control. Soda is the only major constituent needed for conversion of banded iron formation to riebeckite and connate water seems to be an obvious source for this. By the nature of things it will always be impossible to know whether the replaced riebeckite-prone cherts had some essential difference which initiated the crystallisation within them of riebeckite, or whether replaced and unreplaced cherts were at one stage of diagenesis identical, but connate water was available only in some parts of the rocks, where the cherts are now riebeckite.

I am indebted to G. R. Ryan for pointing out that Plate 32 shows a strong correlation between riebeckite content of banded iron formation and the b.i.f./"shale" ratio over a restricted vertical range; the two riebeckite zones occur where this ratio is greatest.

The Upper Fibre Seam

True-scale logging of this seam between two correlatable levels at top and bottom has shown that although fibre is more common towards the top of the seam there is very much less correlation between fibre mesobands. Where fibre mesobands are absent laterally, they are represented by gaps in mesoband sequence. This work is still in progress and is therefore reported on only briefly, but it seems clear that fibre mesobands are dilatational, in marked contrast to the metasomatically formed riebeckites. As has been noted by previous authors, a pre-existing magnetite band is necessary as a seeding layer for the growth of the crocidolite.

No correlation whatsoever between fibre content and riebeckite content is present from the data available so far.

PETROGRAPHY

The following are provisional notes on the petrography of the banded iron formation macrobands only.

Classification of Mesobands

If any attempt is made to expand on the very simplest petrographic description of banded iron formation the range of textural detail becomes so varied as to defy analysis. It has already been noted that essentially the rock consists of a succession of internally consistent mesobands defined by changes in mineralogy and texture, and the first step is to attempt a classification of these. If a strictly qualitative mineral content classification be made, and there are n minerals, then there are $2^n - 1$ possible types of band, ignoring possible textural and quantative subdivisions. There are 13 minerals known to me to be present, listed below:

1. Oxides—
   (a) of silica—Quartz
   (b) of iron—Magnetite
2. Sulphide—Pyrite
3. Carbonates—
   Ankerite-Dolomite
   Siderite
   Calcite
4. Phosphate—Apatite
5. Silicates—
   Riebeckite
   Stilpnomelane
   Feldspar
   Unidentified amphibole
   Unidentified phyllosilicate

With a potential 8,111 different mesoband types this classification of mesobands is clearly inadequate. Fortunately it is possible to classify the mesobands into a comparatively small number of main types, and although some of these are gradational the following classification is useful in practice:

1. Chert
2. Quartz-iron oxide (abbreviated to QIO)
3. Magnetite
4. Stilpnomelane
5. Carbonate—
   (a) Siderite
   (b) Ankerite
   (c) Calcite
6. Riebeckite—
   (a) Mass-fibre
   (b) Crocidolite

This is simply a quantitative mineral classification based on the principal constituent mineral or minerals in each band.

No properly measured estimates of the relative abundance of these types has been made, but there can be no doubt that the first three types constitute 90% by volume of the rock, and the first two about 80%, except within riebeckite zones, where for example the lower riebeckite zone contains an average 11.5% of mass-fibre riebeckite. Only a small proportion of the estimated total 35% of magnetite in banded iron formation would be contained within magnetite mesobands.

Macroscopic Petrography

Chert. The principal mineral content of chert bands lies mainly in the following ranges:

Quartz	50 - 80%
Magnetite	0 - 20%
Carbonate	20 - 30%

Cherts are pale in colour, and are usually of even thickness and lithology. They reach a thickness of 5 inches but this is unusual and ½ - 2 inches is more common. They are characteristically homogeneous internally, except for the regularly striped microbanding which is almost always present. This even alternation of laminae about 0.2 - 0.5 mm thick, defined by slight colour variation is an important and characteristic feature of almost all cherts.

Bands whose thickness is variable may be divided into those in which continuity is maintained and those which are discontinuous. Irregular thickness variation involving contortion with dips up to 40° is rare and usually associated with exceptional carbonate content. Thickness variation not involving dip of microbanding, and caused by irregular transgressive incursion of magnetite-rich material in both top and base of the band is very rare but minor wavy incursions of neighbouring bands involving truncation of the microbanding is quite common. There are several varieties of actual discontinuity. Thin cherts may appear as finely tapering lenticles enclosed in dark QIO material. In such groups there is usually overlap of gaps such that some bands at least are present at any given point. Alternatively the discontinuity may involve the comparatively abrupt truncation of cherts up to 2½ inches thick, with considerable disturbance of the enclosing QIO.

Most commonly the discontinuity in chert bands falls between these two extremes, and a number of lenticles of elongation between 2:1 and 6:1, with intervening gaps about half their length. In this common type of "podding" or "pinch-and-swell structure" the chert edges are often pink-stained and the curved margins meet at about 30°. Pink-staining is not confined to the edges of discontinuous pods. It is a common feature usually about 1-2 mm thick at top and bottom of even chert bands and a local thickening and coalescence of upper and lower pink-staining is often associated with a thinning of the whole chert band. Less commonly, pink-staining is present at top or bottom only of a chert, as a median band, over the whole of a band or in a very clear pink/white definition of the internal microbanding. It is always associated with the conversion of stilpnomelane to fine hematite platelets. Very exceptionally the individual pods may be small and spheroidal or even ellipsoidal with the long axis vertical. In such cases discontinuity is very marked and it may not be possible to follow the original band.

Quartz-iron oxide (QIO). Typically this mesoband type contains:

Quartz	35%
Magnetite	45%
Carbonate	10%
Stilpnomelane	10%

It is a brownish-grey material, often very finely and streakily microbanded, and is gradational into the less pure magnetite bands.

QIO is the characteristic enclosing material of podded cherts, and bands of it vary from almost nothing to about 3 inches. It is usually striped by "sub-bands" caused by relative paucity or abundance of the irregular magnetite microbands. Apart from mineral content the most distinctive difference between QIO and chert mesobands is the absence in the former of the extremely regular alternation of microbands characteristic of the cherts.

Magnetite. There is a gradation from magnetite-rich QIO mesobands to almost pure magnetite mesobands, and the distinction between them is at this stage subjective. Magnetite mesobands are rarely very thick; half an inch is exceptional and the mean would probably be less than a quarter of an inch.

Stilpnomelane. Mesobands with stilpnomelane as the most abundant mineral are thin and rare. They are dark green and of minor interest in the petrography of banded iron macrobands, although shale macrobands may prove to have stilpnomelane as a major constituent.

Carbonates. Pure carbonate bands are not abundant within banded iron macrobands. Green bands consisting almost entirely of fine-grained siderite occur in a few places in the section studied and are stratigraphically among the most consistent of all mesobands. Calcite and dolomite occur as sub-bands bordering chert or QIO mesobands but are never abundant. The occurrence of dolomite-ankerite and siderite within chert and QIO bands is described below.

"Riebeckite" or "Mass-Fibre." The conspicuously blue bands logged by A. B. A. as riebeckite represent other mesoband types replaced to a variable extent by riebeckite. This appears to be volume-for volume metasomatic replacement without structural disturbance of the rock, since ghost mesobands of chert and magnetite are not only clearly recognisable in some of the less completely altered riebeckite bands but their identity as such is confirmed by correlation with other holes in which these particular mesobands are unaffected. This dates the riebeckite as subsequent to the evolution of the main mesoband types by compaction (see below).

Crocidolite. Mesobands of fibrous riebeckite always represent a minor part of the total thickness of the Brockman Iron Formation, even in the mined fibre seams. I have done insufficient work on fibre mesobands as yet to record it in this report.

Microscopic Petrography and Diagenetic Evolution

From the lateral structure of certain chert pods (Figure 2), it is clear that the chert and a smaller vertical thickness of the adjacent QIO material are stratigraphically equivalent, and it seems likely that QIO has developed from chert by post-depositional modification, or diagenesis. The

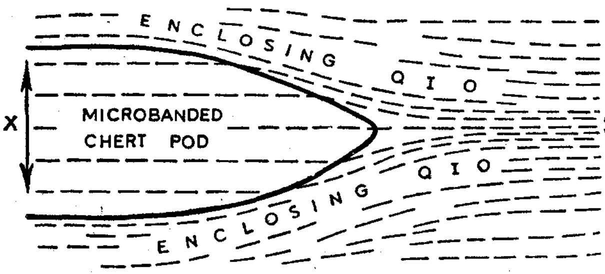


Figure 2—Diagrammatic sketch of textural evidence for equivalence of a greater thickness (X) of podded chert with a lesser thickness (Y) of QIO based on continuity of microbanding. The broken lines within the chert represent lines of ankerite rhombs; those in the enclosing QIO may represent either siderite-rich or magnetite-rich bands.

gradation between QIO and magnetite bands may develop as a result of a more extensive operation of the same process, and from this train of thought I tried to set up a model for a primitive material whose modification during varying diagenetic histories would account for much of the textural and compositional variety. Whatever the nature of such a primitive material may have been at the time of its deposition, and whatever the mechanism of its formation, it is convenient to assume that the least modified representatives of it that are now preserved are chert mesobands with coarse microbanding and that other varieties of chert and QIO were derived from this by diagenesis. The fineness and preservation of the microbanding are indices of the degree of modification. It is not possible to know to what extent present petrographic transitions represent a direct line of descent; two stages of a supposed transition may both be modified derivatives of two entirely different materials which, although derived one from the other, lost their potential to transform during subsequent modification. This concept is largely academic but it is useful to keep at the back of one's mind. The following petrographic account, then, is based on a supposed sequence of diagenetic modification of a primitive material as a means of resolving some of the complexities of the rock:

Primitive Chert. In the least modified cherts there is complete stratigraphic continuity and the microbanding is conspicuous and comparatively coarse. It is defined by ankerite bands about 0.25 mm thick, made up of a virtually continuous mosaic of rhombs about half this dimension across, alternating with bands of chert with an irregular quartz mosaic of average grain diameter about 5μ. Within the quartz are thin green streaks of stilpnomelane flakes. These have only a crude parallel orientation and the actual flake boundaries are difficult to distinguish. There may be 3-6 discontinuous and anastomosing streaks in each chert microband.

In one unusual example ankerite microbands 0.75 mm thick, within which the average grain diameter is still close to 0.125 mm, alternate with discontinuous quartz bands only about 0.2 mm thick, giving a microband (both alternations) thickness of nearly 1mm. The stilpnomelane here is clotted rather than streaky.

A primitively microbanded "chert" with about equal proportions of quartz and ankerite in regularly alternating layers about 0.5 mm thick is regarded as parental to the modifications described below. Two types of modification are distinguishable: "flat modification," in which the chert thickness is evenly reduced and is petrographically altered evenly; and "podded modification," in which compression is uneven, and the end products are chert and QIO. Chert augen remaining within QIO are usually also modified to a variable extent, and such modification has many features in common with flat modification, which is dealt with first.

The different factors which, to some extent simultaneously, are involved in the "flat" diagenesis of a primitive chert are:

1. Stilpnomelane is leached to hematite platelets about 5μ across which develop from finer "dust" left immediately after alteration of the stilpnomelane.
2. The carbonate bands decrease in thickness, the ankerite rhombs become discontinuous with the intermediate quartz mosaic slightly finer than that of the originally stilpnomelane-bearing microbands, the rhombs finally become hollow (with the cores quartz-filled) and siderite appears in association with them, in smaller rhombs.
3. The microbanding gradually becomes finer and its continuity more difficult to follow.
4. Concertina-shaped lines (or plates?) of solid magnetite which have crystal faces along the edges appear. These are referred to as "extended octahedra." They are characteristically discontinuous and patchily distributed, but very frequently there is a tendency for concentration in vertical stacks, like a pile of plates, with alternating vertical gaps. The last feature mentioned is also present at an earlier stage, when it is defined by the preferential concentration of hematite after stilpnomelane.

Whereas in the flat-modification the whole primitive mass ends up as a homogenous squashed relic of the original material reduced to perhaps 20% of its former volume, in podded modification a differentiation into modified chert and QIO is involved. The modification of the chert in the pod follows much the same lines as in flat modification as far as stilpnomelane and carbonates are concerned, except that it is rare for stilpnomelane to be preserved in a pod. On the other hand there is comparatively little microband compression in chert pods, except where they are pink-stained, and virtually no magnetite growth, although a few octahedra are very occasionally present. In one particularly good example on which the microbanding of the QIO can be followed clearly, some 7 mm of chert are represented by about 1.5 mm of QIO. The pink-stained chert edges are caused by removal of carbonates and silica from the modified chert of the pod and the resultant concentration of the fine jaspery hematite from the originally stilpnomelane-bearing microbands.

Quartz-Iron

Oxide (QIO). It has already been pointed out in one example that 7 mm of chert reduce to about 1.5 mm of QIO; here, the chert would have about 30 microband alternations. It is to be expected therefore that the microbanding of QIO will be on a very small scale, nor is it surprising that after this extreme compression its continuity is often difficult to discern. As many as 20 vaguely defined streaks of hematite may be present in a thickness of 0.5 mm, giving a microband width of 0.025 mm. The mineral content of QIO has already been given. There is a general matrix of siderite (a little dolomite may be present) of average grain diameter 15 μ, quartz of the same grain size, rarely forming a continuous mosaic, and stilpnomelane flakes again of about the same length, with parallel streaks of platy hematite. Extended magnetite octahedra exactly like those of the flat-modified cherts are commonly present, and it seems clear that the growth of magnetite was a general, pervasive, late phenomenon in which the magnetite crystallised through the rock in the best local environment. Where the chert had not differentiated the magnetite grew in the chert, but preferentially in the ex-stilpnomelane-bands, and where the chert had differentiated (podded) it grew in the QIO differentiate. This time of growth is supported by the textural relationship of magnetite octahedra to the microbanding: the general streakiness of the matrix is sharply cut off against the edges of the octahedra.

Another common feature of QIO is the presence of quartz augen about 0.5 mm across, often cored with carbonate and associated with magnetite, around which the mircobanding "flows" smoothly. These clearly represent carbonate rhombs pseudomorphed by quartz. It is not clear whether the replacement was before or after compression.

It is difficult to know whether the pink staining represents a late modification of the edges of the chert pods unconnected with the main "chert-to-QIO" transition, or whether it represents an intermediate stage in this transition. If the latter, then it is noteworthy that the siderite of the QIO represents a new generation of carbonate, and is not simply the chert siderite concentrated by removal of the enclosing silica. Its generally finer grain would support this concept.

CONCLUSIONS AND DISCUSSION

Thanks to a uniquely valuable collection of drill cores more data on the internal stratigraphy and petrography of a Precambrian banded iron formation are presented in this report, than have been available in the whole of the extensive previous literature of this puzzling rock. At the start of this report three questions were put as a summary of the objectives of the work. Progress on answering these, together with speculation beyond the evidence presented and ideas for future work, are now summarised.

Three distinct type of banding in the Brockman Iron Formation have been described. Each of these needs an explanation. It has been postulated that all the common mesoband types are derived from one of them—the primitive or coarsely microbanded chert—by diagenetic modification. The common QIO mesoband material is supposed to represent only 20-25% of the volume of its parent chert, and many magnetite bands may represent a more advanced stage of the same process. Thus massive removal of material, presumably in solution in connate water expelled during compaction, is envisaged. Selective analyses of mesobands will show whether this hypothesis is chemically tenable, and indicate the composition of the material removed. If this hypothesis is adopted the problem arises of how the mesobands become defined; any answer to this involves discussion of the nature of the original deposition and of the microbanding.

In common with almost all other workers on Precambrian banded iron formations, I find the spectacular lateral continuity on a minute scale, the lack of any internal textural evidence of detrital origin, and the curious and distinctive chemistry jointly persuasive of an origin for these rocks by chemical or biochemical precipitation. The depth of water is uncertain, but it was probably even all over the basin and was amazingly still. Silicia and ankerite in alternate thin regular layers now form the primitive chert. It is possible that these two materials were precipitated, but equally likely that the silica was in a hydrous gelatinous form and that the ankerite was previously represented by a water-rich mixture of calcium and magnesium carbonates and ferric hydroxide. But it is not certain that the microbanding originated during deposition at all; it may represent some form of liesegang differentiation at shallow depth in a mixed gelatinous sheet. There is an extensive speculative literature on the depositional chemistry of iron formation which there is not space to review or add to here, but one point of microband thickness is worth noting. Allowing for compaction of the order suggested, there are some 35,000 microband pairs in each macroband of the Brockman Iron Formation. If these are supposed to reflect annual changes of depositional chemistry, and an arbitrary 15,000 years are allowed for the associate "shale" macroband, then each cyclic unit represent 50,000 years, and the deposition of the 360 feet of 15 sections studied in detail would occupy some 750,000 years, with a depositional rate of about a foot (of present b.i.f.) every 2,000 years. This seems an acceptable depositional model. A striking feature of the microbanding is its regularity and evenness. A diurnal origin of microbanding would give a high rate of deposition, while any longer time would have to have a regularity absent from any possible cyclic controls of geological environment that are known so far.

Returning now to the question of mesoband origin the problem is one of deciding, if each microband pair represents one year's accumulation of two precipitate types, and if mesoband types are diagenetic differentiates of the resultant material, why particular levels should be modified by diagenesis to different degrees. More information is required here on the numbers of microbands in the different chert types. The commonest type of primitive chert, for example, is about half an inch thick with ten microband pairs; this type commonly lies between magnetite mesobands. On the other hand flat-modified cherts up to 5 inches thick occur with about 350 microbands, and have only very slight internal variation. How does the variety of types arise if the original material is homogeneous? Is the hypothesis fundamentally wrong? Were there breaks in deposition? Were there slight chemical, physical or even thickness differences from time to time, which later exerted an important control over diagenesis? The small-scale rhythmic sequence of cherts about 5 inches thick, referred to above, may help with these problems, none of which are answered.

At the macroband scale the most obvious hypothesis is intermittent (50,000 years, if the hypothesis above is true) sinking of the basin, with depth and proximity to the shoreline the depositional controls. But it is not clear how the two macroband types correspond to particular condition, nor why there is virtually no gradation between the two types. If sudden sinking caused a change from one to the other, gradual sedimentation would not involve an equally sudden change back. As noted above, more comparative work is needed on "shale" tops and bottoms. However, it seems certain, from the comparative uniformity of the Brockman Iron Formation throughout its great thickness, that the basin must have sunk steadily, and sinking still seems the most likely microband control.

G. La Berge (pers. comm.) has suggested a correlation between vulcanicity and shale but the rhythmic alternation of the two man rock types seems too regular for this to be likely.

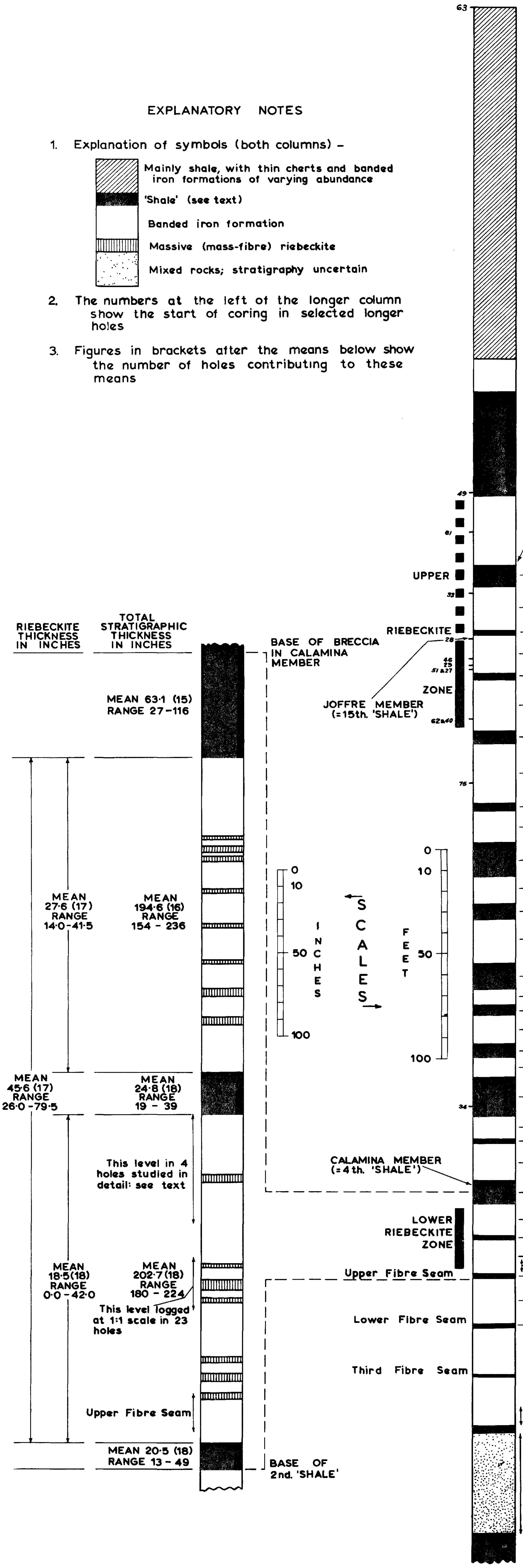
Passing on to the second and third questions, the evidence is now overwhelming that massive (mass-fibre) riebeckite and the economically important cross-fibre riebeckite, or crocidolite, are totally different in origin. Massive riebeckite forms at a late stage of diagenesis of the banded iron formation by metasomatic volume-for-volume replacement of particular "riebeckite-prone" cherts and their adjacent mesobands, probably by the addition of soda from connate water, in an erratic manner. The controls of the process are not known. Crocidolite macrobands are dilatational veins which used a pre-existing magnetite mesoband as a seeding layer. Although it is likely the crocidolite formed still later than the massive riebeckite, which is otherwise the last mineral in the rock to crystallise, it is uncertain to what extent the actual materials of the crocidolite (principally the soda) were derived from pre-existing riebeckite, or were, as in the case of the massive riebeckite, derived from connate water still present.

GEOLOGICAL SURVEY OF WESTERN AUSTRALIA

SUMMARY OF THE INTERNAL STRATIGRAPHY OF THE LOWER PART OF THE BROCKMAN IRON FORMATION IN THE WITTENOOM – YAMPIRE AREA

EXPLANATORY NOTES

1. Explanation of symbols (both columns) –
   - Mainly shale, with thin cherts and banded iron formations of varying abundance
   - 'Shale' (see text)
   - Banded iron formation
   - Massive (mass-fibre) riebeckite
   - Mixed rocks; stratigraphy uncertain
2. The numbers at the left of the longer column show the start of coring in selected longer holes
3. Figures in brackets after the means below show the number of holes contributing to these means



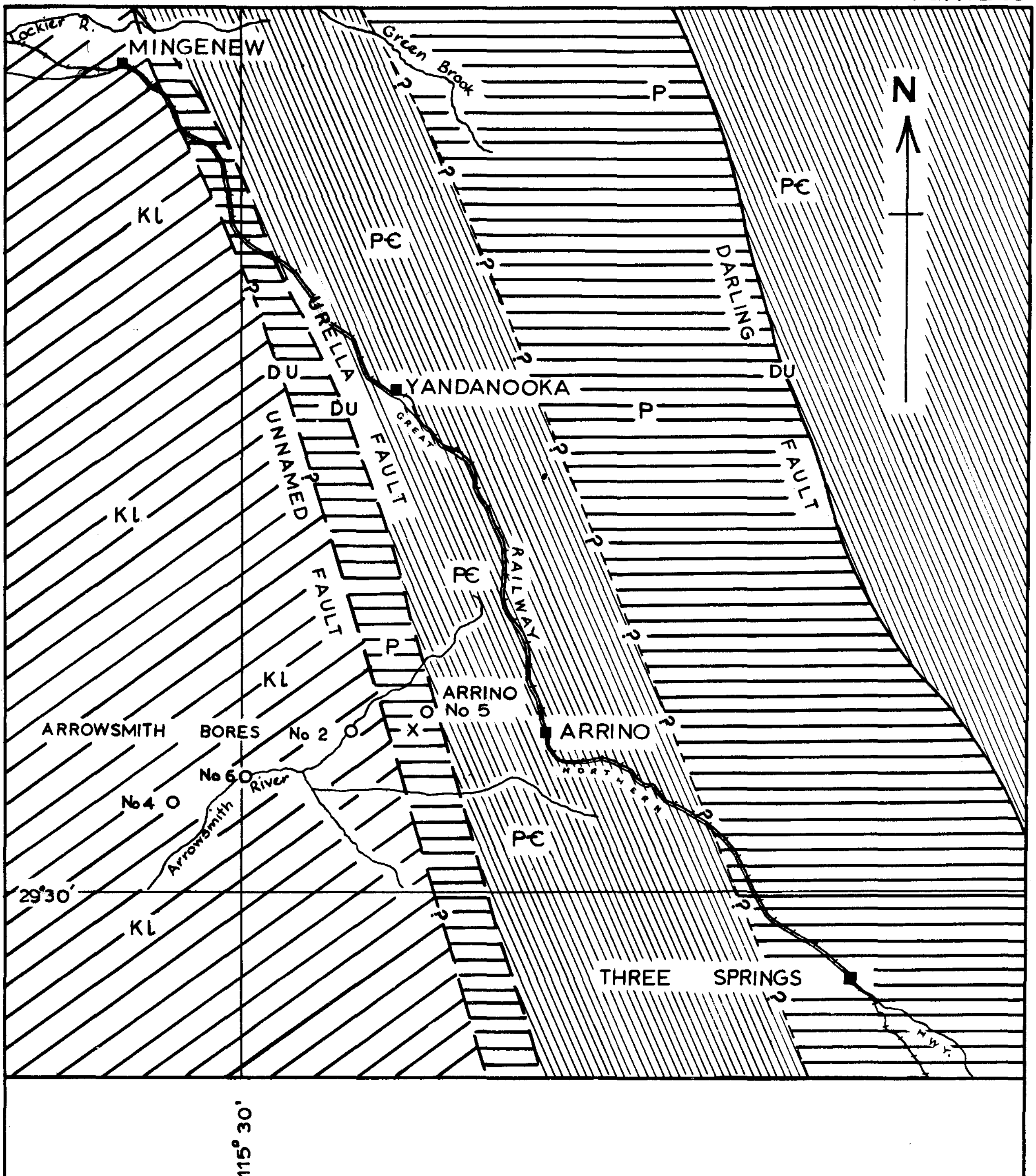
MEAN THICKNESS IN FEET OF NUMBERED 'SHALE' AND BANDED IRON FORMATION MACROBANDS BELOW THIS LEVEL TABULATED HERE

'SHALES'

No.	MEAN	NUMBER OF HOLES USED FOR MEAN	RANGE OF THICKNESS
16	10·3	3	8 – 12
15	2·0	4	2 – 2
14	2·4	9	1 – 3
13	5·6	11	4 – 7
12	2·8	12	1 – 6
11	16·3	12	9 – 20
10	7·8	12	4 – 12
9	11·8	12	6 – 17
8	4·8	12	2 – 8
7	6·2	12	4 – 10
6	19·6	12	16 – 22
5	1·6	12	1 – 3
4	10·3	12	6 – 13
3	2·1	12	1 – 4
2	2·1	12	1 – 3
1	1·8	12	1 – 4

BANDED IRON FORMATIONS

No.	MEAN	NUMBER OF HOLES USED FOR MEAN	RANGE OF THICKNESS
15	20·7	3	19 – 22
14	19·0	4	18 – 20
13	25·0	9	24 – 26
12	28·5	11	27 – 30
11	15·9	12	12 – 18
10	12·0	12	9 – 16
9	22·7	12	18 – 25
8	8·8	12	6 – 15
7	14·6	12	12 – 16
6	9·4	12	8 – 13
5	11·1	12	9 – 12
4	18·7	12	16 – 21
3	15·3	12	13 – 18
2	16·6	12	13 – 18
1	20·6	12	19 – 24



LEGEND

Megafossil Locality	X
Water Bore	O
Lower Cretaceous (KL)	
Permian (P)	
Precambrian (PЄ)	

GEOLOGICAL SURVEY OF WESTERN AUSTRALIA

SKETCH MAP OF SOLID GEOLOGY IN THE ARRINO —— MINGENEW AREA

SCALE OF MILES

4 0 4 8

To Accompany Report By H.S. Edgell 1964

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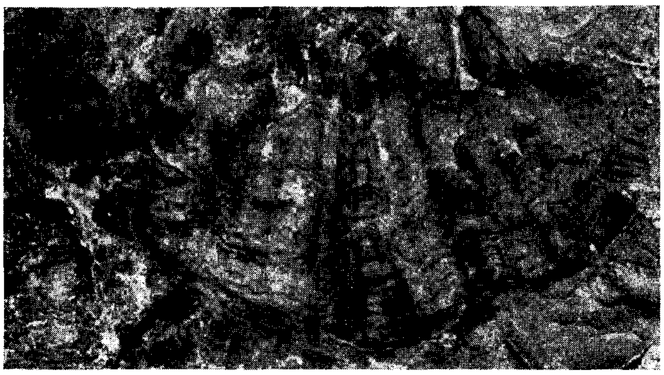

Fig. 1: *Neospirifer musakhleyensis* var. *australis* Foord (x1)
External cast of ventral valve, from 3 miles W. of Arrino.

Fig. 2 *Chonetes pratti* Davidson (x2¼)
Internal cast of ventral valve, from three miles W. of Arrino.

Fig. 3 *Aulosteges baracoodensis* Etheridge, Jr. (x1)
External cast of ventral valve, anterior view from 3 miles W. of Arrino.

Fig. 4 *Aviculopecten subquinquelineatus* McCoy (x1)
External cast of valve, from 3 miles W. of Arrino.

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LOWER PERMIAN FOSSILS FROM OUTCROPS IN THE PERTH BASIN, NEAR ARRINO

by H. S. Edgell

ABSTRACT

Lower Permian megafossils are identified and described from a surface locality in the Perth Basin, 3 miles west of Arrino. They include Artinskian brachiopods and pelecypods indicative of the Mingenew Formation.

In the vicinity of Arrino a narrow Permian fault block lies just west of the Urella Fault where strata had previously been assigned to the Lower Cretaceous. This megafossil assemblage constitutes the southernmost surface occurrence of marine Permian strata yet known in the Perth Basin.

INTRODUCTION

Surface exposures at a locality 3 miles west of Arrino have yielded an interesting assemblage of megafossils. These were collected by D. C. Lowry in 1964. They occur as poorly preserved external and internal casts on fossiliferous slabs of ferruginous silty sandstone.

This surface material was submitted in July, 1964 for age determination and identification of the megafossils. Despite its relatively poor preservation, the distinctive nature of the megafauna has enabled the outcrops to be assigned to the Lower Permian.

Several species of brachiopods can be distinguished in this collection. They include *Aulosteges baracoodensis, Chonetes pratti* and *Neospirifer musakheylensis* var. *australis*. The pelecypod *Aviculopecten subquinquelineatus* is also commonly represented together with occasional *Chaenomya? nuraensis.*

The significance of this faunal assemblage is that it proves the existence of Lower Permian strata in an area formerly thought to be underlain by Lower Cretaceous sediments of the upper Yarragadee Formation. This age determination shows that large scale faulting exists in the Arrowsmith River area on the eastern edge of the Perth Basin.

OCCURRENCE

The fossils described here are poorly preserved on blocks of ferruginous sandstone. They were collected from a hillside 3 miles west of Arrino (see Plate 33), where they occur in loose surface material and also in somewhat obscured outcrop. There is considerable lateritization of surface sediments at this locality, and the largest block collected (about 6 inches square) consists of ironstone with many fossil casts. Three smaller samples collected from the same locality consist of yellow to mauve, medium-grained, silty, micaceous sandstone with frequent pelecypod and brachiopod casts. These rocks have once been calcareous sandstone but are leached, so that only impressions of the shell material now remain.

GEOLOGICAL BACKGROUND

A significant fault known as the Urella Fault, is just east of the megafossil locality. This fault is a major north-northwest trending offshoot of the Darling Fault. The throw of the Urella Fault is not yet known, but it would appear to be considerable and sufficient to wedge a block of Permian strata to the surface in an area of Lower Cretaceous sediments. Thus there is evidently a strip of Lower Permian sediments with megafossils situated west of the Urella Fault. These Late Palaeozoic beds lie between Precambrian granitic gneiss at Arrino itself and Lower Cretaceous siltstone some 5 miles west of the town. Evidently a large fault separates the previously unknown area of Permian strata from Lower Cretaceous sediments to the west. However, the area to the west of Arrino is of low relief, being mostly covered by soil or alluvium with few natural outcrops.

PALAEONTOLOGICAL DATA

The fossils represented as impressions on these strongly ferruginous sandstone specimens include productids, spiriferids and several species of pelecypods. The various species identified are described in detail below.

TAXONOMY AND FOSSIL DESCRIPTIONS

Phylum: BRACHIOPODA.

Superfamily: PRODUCTACEA Waagen 1884.

Family: CHONETIDAE Bronn 1862.

Genus: CHONETES Fischer 1837.

Species: PRATTI Davidson 1859.

(see Plate 34, Fig. 2)

Chonetes Pratti Davidson, The Geologist 1859, p. 116, pl. 4, figs. 9-12.

Chonetes Pratti Davidson, Bullen Newton, 1892, Geol. Mag., v. 9, no. 3, p. 542, pl. 14

Chonetes Pratti Davidson, Etheridge jr., 1903, West. Australia Geol. Survey Bull. 10, p. 23.

Chonetes Pratti Davidson, Etheridge jr. 1907, West. Australia Geol. Survey Bull, 27, p. 19-25, pl. 8, fig. 2; pl. 9, fig. 7; pl. 10, fig. 2.

Material: Four internal casts, principally of the ventral valve, under the registered numbers G.S.W.A. F5285a, F5285b, F5287 and F5288. The internal casts are mostly ferruginised and preserved in fine, decalcified, micaceous sandstone.

Diagnosis: A species of *Chonetes* distinguished by a rather wide hinge line and tendency for the shell to become alate. Four long hinge line spines on each side of the beak. Well defined medium septum in ventral valve and shallow ventral sinus.

Description: The outline of the shell is generally semicircular with a straight hinge line. It is of small size and moderately concavo-convex in profile. Dimensions of the figured specimen are: width = 12 mm; length = 8 mm; depth = 3 mm. The ventral valve has slight ears at the hinge extremities and there is a poorly marked sinus at the anterior margin. There are four long spines on the ventral hinge projecting upwards and outwards on either side of the beak.

Ornamentation of the shell consists of fine radial ribbing. About 40 to 50 fine ribs or costellae occur on a ventral valve of 12 mm width. The internal cast of the ventral valve shows a well marked median septum extending over slightly more than half the shell length. Short thick crura are situated under the ventral hinge on each side of the umbonal cavity. Numerous punctae occur on the internal surface of the ventral valve. Only a few broad growth lines are evident towards the anterior margin of the shell.

Relationships: Typical specimens of the species *Chonetes pratti* Davidson from the Irwin River and Wooramel River districts are larger than those described here and also have a more definite ventral sinus. However, they exhibit a considerable range in size. Smaller specimens of the species from well-preserved material display characteristics identical to those seen in the internal casts collected near Arrino.

There is a close resemblance between these specimens of *Chonetes pratti* Davidson and *C. granulifer* Owen from the Pennsylvanian of North America. Both have a wide hinge with alate cardinal extremities. In the latter, however, the ornamentation is more detailed consisting of very fine costellae, and hinge line spines are more numerous amounting to ten on each side of the beak. The interiors of the ventral valves in these species have short, well-marked crura and very numerous, raised punctae. On the inside lateral and anterior parts of both valves these punctae appear as short tubular spines.

Stratigraphic Distribution: This species is commonly encountered in Lower Permian marine formations in the Perth, Carnarvon and Canning Basins. In the Perth Basin it is found abundantly in the Fossil Cliff Formation. Dwarfed forms also occur as high as the Carynginia Formation. The stratigraphic interval comprising these formations is considered to be entirely within the Artinskian Stage of the Lower Permian (see McWhae and others, 1958; Glenister and Furnish, 1961).

Chonetes pratti also occurs abundantly in corresponding formations in the Carnarvon Basin, particularly the Callytharra Formation, as well as in the Poole Sandstone and Noonkanbah Formation of the Canning Basin. All these strata are of Early Permian age, being dated as Artinskian on ammonoid evidence. The highest stratigraphic horizon at which this species has been found is the Lightjack Member of the Liveringa Formation considered to be Late Artinskian to Kungurian in age (Thomas, 1958). A review of known occurrences of *C. pratti* in Western Australia shows that it is found only in Lower Permian strata.

Superfamily: PRODUCTACEA Waagen 1884.

Family: PRODUCTIDAE Gray 1840.

Genus: AULOSTEGES Helmersen 1847.

Species: BARACOODENSIS Etheridge, Jr., 1903.

(See Plate 34, fig. 3.)

Aulosteges baracoodensis Etheridge, Jr., West Australia Geol. Survey Bull. 10, p. 22, pl. 2, figs. 1-20.

Aulosteges baracoodensis Etheridge, Jr., revised Hosking, Royal Soc. West. Australia Jour., v. 19, p. 33, pl. 1, figs. 1a-c; pl. 2.

Aulosteges baracoodensis Etheridge, Jr., revised Coleman, Bur. Min. Resour. Aust. Bull. 40, p. 36-38, pl. 1, figs. 1, 3, 4 and 6.

Material: External cast of most of one ventral valve under the registered number G.S.W.A. F5291. The external impression is well preserved in a highly ferruginized rock and shows much detailed ornamentation.

Diagnosis: Large species of *Aulosteges*, subquadrate in outline, ornamented with very numerous small sub-erect and reclined, spine bases giving a somewhat striate appearance.

Description: The specimen preserved represents a large productid with a subquadrate outline. The ventral valve has a width of 60 mm and a length of at least 50 mm, although the anterior margin of the shell is not preserved. Maximum thickness of the shell is about 35 mm.

There is a strong blunt umbo on the ventral valve, flanked by weakly developed ears. A broad sinus is also developed on this valve. Most distinctively the shell possesses fine ornamentation consisting of many elongate spine bases and some which are small and erect. This gives the shell a closely ribbed appearance with ribs about 1 mm apart. Concentric growth rings are faintly developed.

Relationships: Aulosteges baracoodensis Etheridge Jr., is distinguished from *A. spinosus* Hosking by its larger size, more quadrate outline and less prominent spines. A similar shaped form of *Aulosteges* known as *A. lyndonensis* has less frequent and finer spines than *A. baracoodensis*. Finally comparison with topotypes of *A. baracoodensis* and a hypotype figured by Etheridge Jr. (West. Australia Geol. Survey Bull. 58, p. IV, fig. 11) shows that the specimen from Arrino belongs to that species.

Stratigraphic Distribution: All specimens of *Aulosteges baracoodensis* are from Lower Permian strata, particularly in the Perth and Carnarvon basins of Western Australia. At the type locality Baracooda Pool, Arthur River, in the Gascoyne district the species occurs in the Callytharra Formation of Artinskian age. Corresponding beds of the Fossil Cliff Formation in the Irwin River district also contain this distinctive productid.

Superfamily: SPIRIFERACEA Waagen 1883.

Family: SPIRIFERINAE Schuchert 1913.

Genus: NEOSPIRIFER Fredericks 1919.

Species: MUSAKHEYLENSIS Davidson 1862.

Variety: AUSTRALIS FOORD 1890.

(See Plate 34, Fig. 1.)

Synonomy:

Spirifer fasciger on Keyserling 1846, Wissensch, Beobacht, auf einer Reise in das Petschoraland im Jahre 1843 p. 229, Tab. 8, figs. 3, 3a, 3b.

Spirifera Moosakhailensis Davidson 1862, Geol. Soc. London Quart. Jour. v. 18, p. 28, pl. 2, fig. 2a-c.

Spirifera Musakheylensis Waagen, 1883, Pal. Indica, Ser. 13, Salt Range Fossils, Fasc. 4, no. 2, p. 512, pl. 55.

Spirifera Musakheylensis var. *australis* Foord, 1890, Geol. Mag. v. 7, p. 147-149, pl. 7, fig. 2 and ? pl. 5, fig. 12.

Spirifer musakheylensis var. *Australis*, Foord; in Hosking 1931, Royal Soc. West. Australia Jour. v. 17, p. 23-24, pl. 7, figs. 1-3.

Neospirifer musakheylensis (Davidson) var. *australis*, Foord, this paper.

Material: One external cast of the ventral valve preserved with details of ornamentation and outline as an ironstone impression, under the registered number G.S.W.A. F5292.

Diagnosis: A moderately large spiriferoid with a transversely rhomboidal outline and moderately convex valves. Distinctively ornamented by numerous small ribs in groups of larger plications and traversed by numerous conspicuous growth lines.

Description: The shell has a width of approximately 70 mm and a length of 40 mm. It has somewhat rounded lateral extremities and is subrhomboidal in outline. There is a wide, plicate sinus in the ventral valve and from four to five major ribs on each of the lateral slopes. Numerous smaller ribs appear faintly on the major ribs. This pattern of double ribbing is intersected by very numerous, sharp, projecting growth laminae. There are not more than two concentric frill laminae per millimetre.

Relationships: The specimen examined does not show details of the umbo or hinge line. On the basis of shape and size it is very similar to hypotypes in the palaeontological collections of the Geological Survey of Western Australia. The numerous ribs crossed by prominent growth lines are a common characteristic. However, small plications on the larger ribs are more numerous and more prominent on well preserved specimens.

"Spirifer" (Neospirifer) hardmani Foord shows a resemblance to the Arrino material in overall size and shape, although it is slightly more quadrate. In addition, *N. hardmani* has numerous evenly developed, radiating ribs and these are not plicated or intersected by prominent growth laminae.

Hosking (1931, p. 23) has stated "there remains no doubt that *S. fasciger* and *S. musakheylensis* are identical and that Keyserling's name takes precedence." In the absence of comparative material from the Salt Range representing *Neospirifer fasciger Keyserling* I have referred our specimen to Foord's variety which is commonly known in Australian literature and collections.

Although originally assigned to the genus *Spirifera* by Davidson (1862) and later to *Spirifer* by Hosking (1931) the form figured by Foord (1890) is undoubtedly a *Neospirifer* in modern spiriferoid nomenclature. It has the general large transverse outline and possesses the characteristic fasciculate ribbing. The specimen examined is thus referred to here as *Neospirifer musakheylensis* Davidson var. *australis* Foord.

Stratigraphic Distribution: The type locality of *Neospirifer musakheylensis* var. *australis* is given by Foord as the Gascoyne River. Although this is not a specific reference almost identical hypotype material is figured by Hosking (1931, pl. 7, fig. 1) and comes from ½ mile west of Callytharra Springs in the Callytharra Formation. The age of this very fossiliferous formation is known to be early Artinskian. Other occurrences of this spiriferoid are all from lower Permian strata. These include the Byro Group at Byro Station, Lower Murchison River district and the Callytharra Formation, 20 miles north of Barrabiddie, in the Minilya River district. *Neospirifer musakheylensis* is also recorded from the Lower Permian Noonkanbah Formation in the Christmas Creek area of the Canning Basin (Wade, 1924).

Phylum: MOLLUSCA.

Class: PELECYPODA Goldfuss.

Superfamily: GRAMMYSIACEA.

Family: PHOLADOMYIDAE Gray.

Genus: CHAENOMYA Meek 1865.

Species: NURAENSIS Dickins 1963.

Synonomy:

Chaenomya sp. nov. Dickins 1957, Bur. Min. Resour. Aust. Bull. 41, p. 29, pl. 4, figs. 10-12.

Chaenomya? nuraensis Dickins 1963, Bur. Min. Resour. Aust. Bull. 63, pp. 52-53, pl. 6, figs. 10-14.

Material: Two external impressions of the right valve of this pelecypod are preserved in leached, silty sandstone, under the registered numbers G.S.W.A. F5286a and F5286b.

Diagnosis: Elongate sub-rhomboidal shell with long posterior part. Umbo broad, sub-erect. Posterior dorsal edge almost straight making a narrow obtuse angle with the rounded posterior margin. Dorsal part of anterior margin short and oblique to shell length.

Description: The outline in this species is traversely elongate and very inequilateral with a high and long posterior part. There is a very broad umbo and a short anterior area. The shell is marked by its almost straight postero-lateral margin, which makes a broad angle with the rounded postero-ventral margin. A short and slightly oblique anterior margin is present. Of moderate size and no great thickness the valves show numerous lightly marked growth lines. There is probably a slight posterior gape. Typical shell dimensions are: length = 35mm; height = 20 mm; thickness = 5 mm.

Relationships: In casts of this pholadomyid type shell identical characteristics can be seen to those described by Dickins (1963) for the species *Chaenomya? nuraensis.* However, his original description of this species is based on casts of one valve. Conjoined or separate valves have not been studied and assignment to the genus *Chaenomya* is as yet provisional.

Stratigraphic Distribution: This species has been found in Western Australia only in the Carrandibby Formation, in the Wooramel River district and in the Nura Nura Member, in the Fitzroy River area. Both these stratigraphic units are Lower Permian and correlative with the Fossil Cliff Formation of Artinskian age in the Perth Basin.

Superfamily: PECTINACEA Reeve.

Family: AVICULOPECTINIDAE Etheridge Jr. Emend. 1906.

Genus: AVICULOPECTEN McCoy 1851.

Species: SUBQUINQUELINEATUS McCoy 1847.

(See Plate 34, fig. 4.)

Synonomy:

Pecten comptus Dana (non McCoy) 1847, Am. Jour. Sci., v. 4, p. 160.

Pecten sub-5-lineatus McCoy 1847, Ann. Mag. Nat. Hist., v. 20, p. 295, pl. 17, fig. 1.

Aviculopecten subquinquelineata McCoy, Etheridge, Jr., 1880, Royal Phil. Soc. Edinburgh Proc., v. 5, p. 297, pl. 15, fig. 52.

Deltopecten subquinquelineatus (McCoy), Etheridge Jr., 1907, West. Australia Geol. Survey Bull. 27, p. 22-23, pl. 5, figs. 1-3.

Deltopecten subquinquelineatus (McCoy) var. *comptus* Dana, Fletcher 1929, Aust. Museum Rec., v. 17, no. 1, p. 23, pl. 13, figs. 1-4.

Material: Two partly preserved, external casts of the left valve under the registered numbers G.S.W.A. F5293 and F5284.

Diagnosis: Pectiniform, nearly equilateral, biconvex; cardinal margin auriculate and slightly less than maximum width. Radial ribs increasing by intercalation.

Description: Casts of the shell show that it is truncato-orbicular in outline with well-developed ears and almost equilateral. Its maximum width lies about midway between the umbo and the rounded, ventral commissure. Ornamentation consists of from 15 to 25 primary ribs with numerous, fine ribs intercalated ventrally. Growth lines are not prominent and are widely spaced.

Relationships: Aviculopecten subquinquelineatus cannot be assigned to the genus *Deltopecten* as its ornamentation does not consist solely of large radiating ribs. It has in addition many finer ribs intercalated towards the ventral margin. There is no doubt that the species has been incorrectly referred to *Deltopecten* in Western Australia literature since 1907. Comparison with hypotype specimens of *A. subquinquelineatus* figured by Etheridge (1907) and now in the palaeontological collection of the Geological Survey shows that the Arrino specimens are almost indistinguishable in size, shape and nature of ribbing.

Specimens from the Wooramel River district, figured by Hosking and named *Deltopecten subquinquelineatus* var. *comptus* Dana also show similar characteristics to our material. They are definitely *Aviculopecten* with ribbing arranged in ranks, and probably belong to the species *A. subquinquelineatus* McCoy but cannot be referred to the variety *comptus* Dana. It has been pointed out by Etheridge (in Jack and Etheridge, 1892) that Dana's name of *comptus* was preoccupied by McCoy for another species from the Carboniferous of Ireland.

Stratigraphic Distribution: Known occurrences of *Aviculopecten subquinquelineatus* in Western Australia are all from Lower Permian beds. It is recorded abundantly from the Madeline Formation in the basal part of the Byro Group, lower Murchison River district and from the Mingenew Formation about 1½ miles east of Mingenew, Perth Basin. Both these formations are of Artinskian age. There is a marked similarity in the limonitic sandy lithology of the Mingenew Formation and that of the outcrop material from Arrino. Materials from both localities contain abundant *A. subquinquelineatus* with almost identical, fine, intercalated, radial ribbing.

FACIES

The presence of large productid and spiriferoid brachiopods as well as pholadomyid and pectiniform pelecypods in the megafauna near Arrino provides good evidence of depositional conditions. They indicate that the strata were formed in a shallow marine environment possibly in the inner neritic zone. The rocks in which the Arrino fossils are found confirm this view since they are poorly sorted micaceous sandstones now largely ferruginized due to weathering. The original nature of the rock has been a very fossiliferous calcareous silty sandstone.

GEOLOGICAL AGE

All the megafossil species identified are known to be confined to Lower Permian formations in Western Australia. These formations are richly fossiliferous and are known to be of Artinskian age on the basis of their brachiopod, pelecypod and ammonoid faunules. There is no doubt that the fossil material is Early Permian and Artinskian according to recent correlations (McWhae and others, 1958; Furnish and Glenister, 1961: Dickins, 1963).

CORRELATION

The megafauna indicates a general correlation with formations such as the Mingenew Formation, Fossil Cliff Formation, Callytharra Formation and the Nura Nura Member of the Poole Sandstone. These are all very fossiliferous, Lower Permian rock units well known in the stratigraphy of Western Australia. They are considered to be stratigraphically equivalent, with the exception of the Mingenew Formation. In recent studies Dickins (in McWhae and others, 1958; in McTavish, 1961; Dickins, 1963) has shown that this enigmatic formation is approximately correlative with the Madeline Formation of the Wooramel River and the lower part of the Byro Group in the Kennedy Range.

Investigation of the known vertical ranges of megafossils collected near Arrino show that they are mainly recorded from beds younger than the Fossil Cliff Formation. Thus, the pelecypod *Aviculopecten subquinquelineatus*, which occurs so abundantly in the Arrino megafauna is known principally from the Madeline Formation, in the lower Byro Group and from the Mingenew Formation itself. In the latter beds *A. subquinquelineatus* is commonly preserved as casts. These occur in a ferruginous silty sandstone almost identical in lithology with the fossiliferous samples collected in the Arrino area.

A recent water bore, Arrowsmith River No. 5, also encountered Lower Permian strata between the sampled depths of 90 feet and 120 feet. This bore is approximately 3 miles west of Arrino. The samples of dark grey claystone were examined palynologically and found to contain the characteristic *Nuskoisporites gondwanensis* Assemblage. This is typical of the Lower Permian and the strata examined from this bore belong to the Holmwood Shale. A few miles further to the west numerous bores for water in the Arrowsmith River area have reached the Lower Cretaceous Yarragadee Formation at shallow depths. At Arrino itself and in a belt north-northwest of the town Precambrian rocks are present.

CONCLUSIONS

At a locality some 3 miles west of Arrino scattered outcrops of ferruginous silty sandstone have yielded a distinctive Lower Permian megafauna. This consists of the brachiopods *Aulosteges baracoodensis, Chonetes pratti* and *Neospirifer musakheylensis* var. *australis* as well as the pelecypods *Chaeomya? nuraensis* and *Aviculopecten subquinquelineatus*. All these species are known only from the Lower Permian and are confined to strata of Artinskian age.

Identification of this fossil assemblage has considerable geological significance. It shows that Lower Permian strata occur at the surface a few miles west of Arrino in an area previously thought to be underlain by Lower Cretaceous sediments. This is the southernmost surface occurrence of Permian strata known in the Perth Basin west of the Urella Fault.

The ferruginous sandstone in which the fossils are found can be assigned to the Mingenew Formation. It is correlative with the lower Byro Group of the Carnarvon Basin, or approximately with the Carynginia Formation of the Perth Basin Permian sequence.

Lower Permian outcrop and subsurface sediments just west of Arrino are situated in a narrow north-northwest trending fault block bounded by Precambrian rocks to the east and Lower Cretaceous sediments to the west. This block is downthrown by the Urella Fault against Precambrian rocks to the east. Another major fault 4 miles west of Arrino allows Lower Cretaceous strata to be downthrown at least 6,000 feet against this narrow Permian fault block. The Mingenew formation at its type locality some 1½ miles east of Mingenew is bounded by similar faults and is probably in the same fault block as the Arrino megafossil locality.

Palaeontological evidence of the Lower Permian Mingenew Formation just west of Arrino provides a further indication of the strong fault pattern which dominates geological structure in the Perth Basin.

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TECHNIQUES IN THE RECOVERY OF SPORES AND POLLEN FROM SURFACE SEDIMENTS

By H. S. Edgell

ABSTRACT

Palynological techniques are described by which spores and pollen may be recovered from surface samples of various lithological types. These methods involve limited oxidation and base treatment as well as controlled heavy liquid separation. They have been used in the laboratory of the Geological Survey of Western Australia during the last three years and have provided useful data for the majority of outcrop samples submitted.

INTRODUCTION

In earlier palynological investigations in Western Australia the study of surface samples has been avoided. This is because simple preparation of some outcrop samples yielded no spores or pollen grains and it was held that surface weathering had effectively destroyed any determinable palynomorphs. The more favourable dark, argillaceous or carbonaceous subsurface samples have been primarily selected in past work. While these certainly provide the most diverse microfloral assemblages, such ideal lithologies are often unavailable. This is most commonly the case with outcrop material or samples from shallow depths where it may be critical to know the age, facies and formation represented. Palynological age determinations of this type are of particular value in the construction of regional maps and in hydrological investigations. In the latter case there is often a major interest in shallow, less saline aquifers as well as in the age and distribution of intake beds.

MATERIAL

Methods applied in the recovery of spores and pollen from surface samples vary widely according to the type of lithology. Certain kinds of surface weathering or shallow leaching may entirely remove all initial carbonaceous material from a sediment. This includes the complex but highly acid resistant organic sporine or sporopollenine which forms the walls of spores and pollen grains. The effect of weathering appears to take place down to depths of at least 200 feet in permeable sediments in the arid or seasonal rainfall areas of Western Australia. This is the case with the poorly sorted siltstones and sandstones of the Yarragadee Formation in the Allanooka water bores.

Samples of considerably different lithology were examined from surface and subsurface occurrences. These ranged from lignites and carbonaceous black shales through to siltstones and poorly sorted sandstones. It was found possible to recover plant microfossils from all of these sediment types except where weathering had produced excessive ferruginization. Surface silicified sandstones of the "grey billy" type yielded rare unoxidized spores and pollen grains despite the low content of organic material.

PROCEDURES

In general normal palynological preparation methods were used, namely the Schulze method for oxidation of carbonaceous material such as dark shale and coal as well as maceration methods for siliceous, clastic sediments. The procedures when applied uniformly often failed to produce results due to excessive oxidation of a very small content of palynomorphs.

Modifications of the usual steps taken in palynological preparation were found necessary for different kinds of surface sediments. In addition various methods were employed to separate the rare organic content of surface samples from a comparatively large volume of fine undissolved mineral particles. The principal procedures used in the palynological preparation of different types of sediments are given below.

PREPARATION OF CLASTIC SEDIMENTS

The preparation of fragmental rocks such as claystones, siltstones and sandstones mainly involves the removal of inorganic, mineral material with hydrofluoric acid. Many additional procedures are required in this method such as neutralization, oxidation, centrifugation and staining. The processes used by the Geological Survey are as follows:

Dark Shales and Siltstones

1. Crush approximately 6 gms of rock sample to fragments not exceeding 3 mm.

2. Apply dilute HCl to test for the presence of carbonates.

3. If effervescence takes place treat the material with 20% HCl for one hour or until reaction ceases. Wash several times with distilled water.

4. Transfer 4 gms of the decalcified or original non-calcareous sample to a platinum dish and add 30% HF to fill half the dish.

5. Stir with a glass rod and boil gently under a fume hood for about 10 minutes or until the original volume is reduced by about two-thirds. Then add 10% HCl to restore the original volume.

6. Agitate gently using tongs and transfer the contents to a plastic centrifuge tube.

7. Centrifuge once for 30 seconds at 2,500 r.p.m. and follow by washing with distilled water.

8. A small quantity of $KClO_4$ (½ gm or less) is added to the wet residue and mixed thoroughly with a glass rod.

9. Add concentrated HNO_3 to fill about ⅓ of the centrifuge tube. Stir the mixture carefully and allow to stand for 3 minutes. Proportionately less time is required with lighter, less carbonaceous samples.

10. Wash with distilled water, stir and centrifuge. Repeat this process 3 times.

11. Add dilute (5%) NaOH to fill about ⅓ of the tube, then stir, transfer to a small beaker and heat until simmering. Do not boil as the caustic solution ultimately removes spore and pollen exines.

12. Wash 3 times with distilled water immediately after alkali treatment until a clear solution is obtained.

13. Concentrated HNO_3 is then added to fill about 1/6th of the centrifuge tube, the solution is stirred and washed with water 3 times.

14. Add a similar small quantity of dilute NaOH, stir and quickly wash out with water several times.

Sandstones, light claystones and kaolinites

Light coloured or leached clastic sediments are generally oxidized in nature and have a very low content of spores and pollen. They require no further oxidation by treatment with boiling HF and alkalies. In the preparation of such samples it is necessary to modify the maceration procedure applied to carbonaceous sediments.

1. The outer portions of these surface samples must be scraped off or removed with a rock saw. If this is not done there is resultant misleading contamination by Recent spores and pollen grains.

2. A much larger sample of from 10 gm to 20 gm needs to be disintegrated to a maximum grain size of 3 mm. Extra care should be taken that all crushing implements, vessels and stirring rods are thoroughly cleaned with distilled water.

3. Transfer the crushed sample to a large polycarbonate beaker, cover with twice its volume of cold 50-60% HF, stir and allow to stand for 12 to 24 hours.

4. Add twice as much distilled water as fluid in the beaker. The specific gravity is thus reduced allowing pollen to settle when centrifuged.

5. Decant and centrifuge the material in the beaker and wash several times in distilled water.

6. The residue is then washed into a small beaker with 50% HCl and warmed to remove undissolved fluorides formed at an earlier stage. Follow by rewashing with distilled water 3 times.

7. Treat the residue for 10 seconds or less with a very small amount of $KClO_4$ and HNO_3 and follow by several rinses with distilled water.

8. Add a small quantity of dilute NaOH (5%), stir with the residue and wash twice without allowing to stand. The residue is then ready for staining or further separation of spores and pollen using heavy liquids.

Some outcrop or shallow subsurface samples of a leached argillaceous nature yield a relatively large quantity of yellowish or whitish gel after treatment. This can be removed by agitation alternately with dilute HCl and NaOH for very short periods with intermittent washing and centrifuging.

PREPARATION OF COALS

The palynological preparation of surface coal samples is less complex as carbonaceous material predominates. Oxidation is necessary to remove a large amount of organic debris and to separate the acid insoluble spores and pollen. This is primarily achieved by use of Schulze solution, which consists of a rather explosive mixture of $KClO_4$ and concentrated HNO_3.

Preparation procedures used for coal samples are as follows:

1. Crush several grams of the rock to a grain size of 1 mm.

2. Place crushed material in a beaker with Schulze solution, consisting of one part of saturated aqueous $KClO_4$ solution to 2 or 3 parts of cold, concentrated nitric acid. About 3 times as much Schulze solution should be added as the volume of crushed material.

3. The oxidizing process should be allowed to proceed for at least 12 hours.

4. After oxidation the residue is washed several times by centrifuging and decanting with distilled water.

5. A solution of 30 cc of 5% KOH is then added to the residue, stirred and allowed to stand for a short period. If allowed to remain in alkali or Schulze solution for too long spore and pollen exines swell and may dissolve completely.

6. After treatment with a base the residue is washed 3 times in distilled water. It is then ready for staining and slide preparation. If mineral material is present in large quantities in the initial slide, treatment for 12 hours with 50-60% HF is necessary. Alternatively water soluble heavy liquid separation may be used to remove mineral particles.

HEAVY LIQUID SEPARATION

After the above maceration with HF, Schulze solution and other reagents, the majority of mineral material has been dissolved away. In many cases, however, an appreciable cloud of fine undissolved mineral remains and obscures the acid insoluble plant micro-fossils which have been retained. The most effective method of separating organic particles from inorganic material is by heavy liquid separation with controlled centrifuging. This method is the basis for success in recovering spores, pollen grains and microplankton from surface samples with a very depleted organic content.

There is substantial difference in the specific gravities of all varieties of undissolved mineral particles (e.g. fluorite 3.2, quartz 2.6 and calcite 2.7) and those of organic particles (between 1.3 and 1.7). This provides an ideal basis for separating palynomorphs from mineral material which often masks them completely in the final macerated residue. However, any separation scheme needs to avoid heavy liquids which are organic solvents and those which are non-water miscible. Solutions of $ZnCl_2$ or $ZnBr_2$ both fulfil these requirements and although the latter is less viscous and probably preferable it is an expensive reagent. In the Geological Survey we have found a saturated solution of $ZnCl_2$ of specific gravity 1.95 to be very adequate for separation of organic material. It is necessary to keep a periodic check on this specific gravity with a hydrometer and to see that there is a minimum of water with the macerated residue when the heavy liquid is added. If this is not observed the specific gravity falls below 1.95 and an effective separation of pollen and spores cannot be achieved.

The heavy liquid separation method adopted in our laboratory is similar to that outlined by Funkhouser and Evitt (1959). It consists of the following steps:

1. Approximately 8 cc of saturated $ZnCl_2$ solution of specific gravity 1.95 are mixed thoroughly with the residue and transferred to a 28 cm length of plastic tube of about 15 mm diameter.

2. The flexible tube and its contents are then agitated with fingers over both outlets.

3. Double the plastic tubing and place it in a centrifuge tube. Centrifuge at 1,500 r.p.m. for at least 15 minutes. This is generally sufficient to sink all mineral particles, but if the final slide still retains fine inorganic material the process may be repeated at slightly higher speeds—2,000 r.p.m. for as long as 30 minutes.

4. After centrifuging with heavy liquid a black layer of organic particles appears at the top of the liquid in each arm of the doubled tube. Pliers are used to tightly close off the plastic tubing just below this organic layer. In some sediments where there is a minute amount of organic material no layer can be seen after separation, but many particles are observable on the surface in indirect light. The surface layer in each half of the folded tube may be sucked off with an eyedropper in such cases and then washed and centrifuged.

5. The uppermost heavy liquid containing organic material is then placed in a conical based centrifuge tube together with a few drops of 10% HCl. This acidification prevents the formation of insoluble $Zn(OH)_2$.

6. After filling with distilled water the polycarbonate centrifuge tube is given a short centrifuging for a few minutes at 3,500 r.p.m. The liquid is carefully decanted except for a minimum amount containing the organic residue.

7. In staining the small organic fraction recovered from surface samples only 1 or 2 drops of Safranin Y are added. The stained residue is washed and centrifuged again. It is then ready for examination on a slide in a glycerine jelly mounting medium, suitably cover slipped and sealed.

Certain types of clastic sediments particularly glauconites or glauconitic sandstones yield a final residue which aggregates in large clumps of indistinguishable spores and pollen grains. By adding a few drops of detergent and shaking as much as possible by hand some of these clusters break up. A more effective method of disaggregating organic residues of this type is to subject them to 5 to 10 seconds ultrasonic treatment in a narrow phial with ⅛-inch diameter probe vibrating at 20 kilocycles per second.

APPLICATIONS

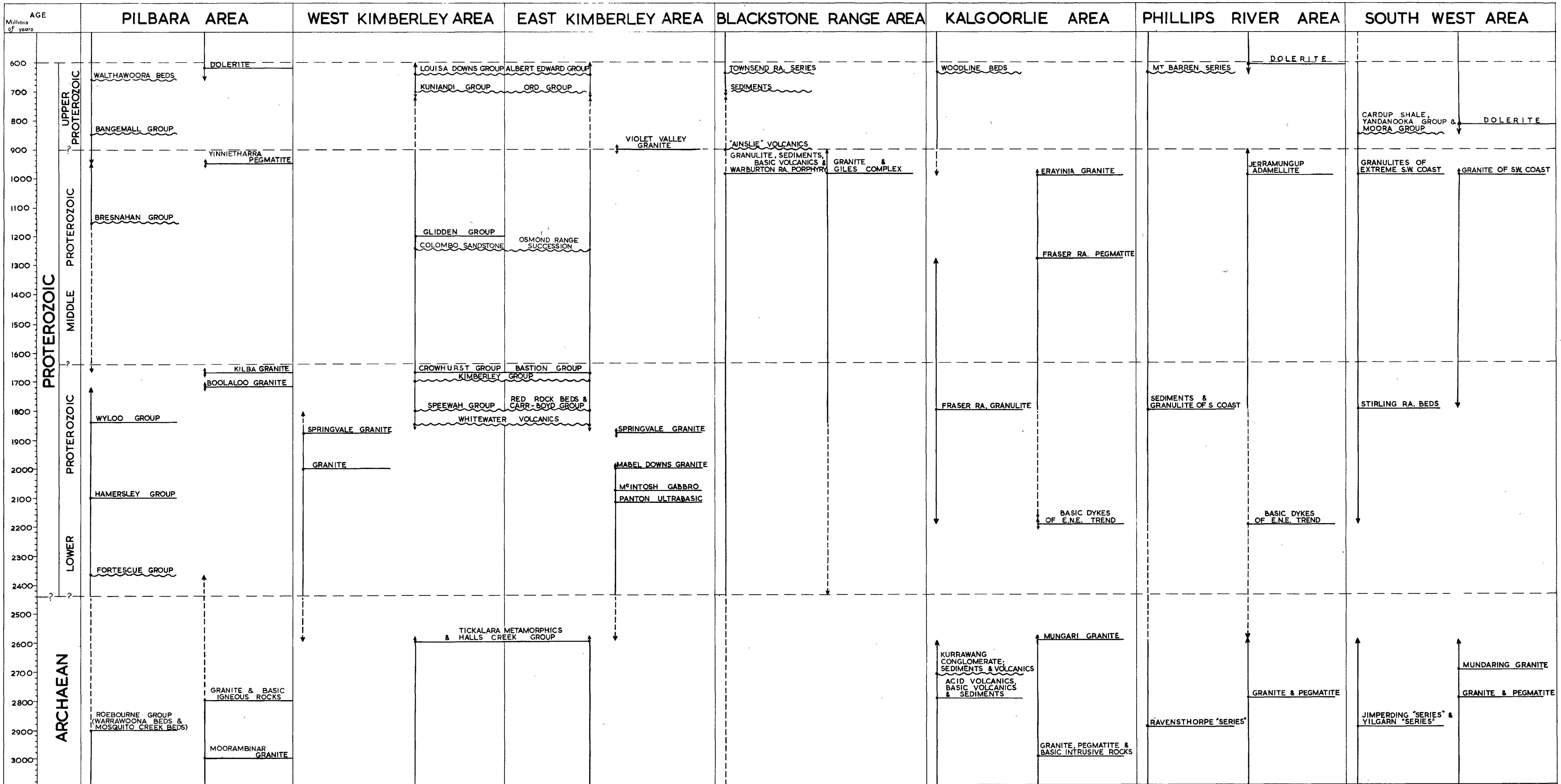
The recovery of spores and pollen grains from outcrop samples is most useful in general geological work. Although these rocks are usually much leached, weathered and improverished in organic content, it is essential for the geologist mapping an area to know their geological age and the formation to which they may be assigned. Knowledge of this type can otherwise only be obtained from the rare occurrences of larger fossils or by extensive drilling. Even then shallow subsurface material may be leached to a depth of several hundred feet. Construction of a geological map showing time-rock units depends largely on the palaeontological dating of surface outcrops. Age determinations and recognition of surface formations cannot always be made as diagnostic megafossils and larger microfossils are often absent. Most sediments contain plant microfossils no matter whether they are of marine or continental origin. Palynology thus provides an important key to stratigraphic interpretation of surface outcrops and especially to their mapping and correlation.

In conjunction with geological mapping in the southern Perth Basin the age of many outcrop samples has been determined palynologically. Well preserved Upper Jurassic and Lower Cretaceous microfloral assemblages have been recognised as well as a large number of Quaternary outcrops with the typical *Myrtaceidites eucalyptoides* microflora.

Surface samples collected by geologists of the Geological Survey from the Wilkinson Range Beds at localities in the Officer Basin have also been dated as Lower Cretaceous on the basis of spores and pollen. These beds cover a very large area north of the Eucla Basin and had previously been assigned to the Permian System.

Investigations for water in the Kalamunda area have been assisted by the dating of leached white kaolinitic material from just below the valley-filling laterites at depths of 20 to 30 feet. The age of these laterites has now been determined as post-Pliocene on palynological evidence.

Regional mapping of the Mt. Ramsay, Roebourne and Yanrey 1 : 250,000 Sheets has also been assisted by the recovery of spores and pollen grains from surface sediments enabling the dating of Pliocene and Quaternary outcrops.



AGE OF UNIT

PROPOSED

PROPOSED (UNIT RESTS WITH A BASAL UNCONFORMITY)

PROBABLE RANGE WITHIN WHICH THE UNIT MAY FIT

POSSIBLE RANGE WITHIN WHICH THE UNIT MAY FIT

TENTATIVE POSITION OF TIME BOUNDARY ?

PROVISIONAL SUBDIVISIONS OF THE PRECAMBRIAN IN WESTERN AUSTRALIA

GEOLOGICAL SURVEY OF WESTERN AUSTRALIA 1964

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CONCLUSIONS

Through the modification and improvement of normal palynological techniques more sensitive methods of preparation have been developed. These have enabled the writer to recover spores and pollen from numerous outcrop samples which are generally weathered and oxidized. Leached clastic surface samples may now yield plant microfossils diagnostic of their age. A notable exception is that of strongly ferruginized sediments. Even in this case, however, a ferruginous outer zone may sometimes be removed from the outcrop sample giving a silicified or unoxidized inner part suitable for palynology.

These techniques require the removal of the exposed surfaces of samples which may contain contaminating recent palynomorphs. According to the type of lithology, it is necessary to adjust the amount of material prepared as well as the quantity and duration of Schulze and alkali treatment.

The main reason for successful recovery of identifiable spores, pollen and microplankton from samples of impoverished organic content is controlled heavy liquid separation. It is possible to separate all mineral particles from the lighter organic fraction of the sediments.

The ability to recognize the age of outcrops by the recovery of spores and pollen, is obviously valuable to geological mapping. The techniques described are those which have provided the most favourable results in the preparation of material for various palynological investigations. They are outlined here in the hope that they may prove useful to other workers in the field of palynology.

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PROVISIONAL SUBDIVISIONS OF THE PRECAMBRIAN IN WESTERN AUSTRALIA

The accompanying chart (Plate 35) sets out the present state of knowledge of Precambrian geochronology in Western Australia.

Rocks older than the Palaeozoic occupy more than half the area of Western Australia. These rocks have a complex history and have been formed during a large span of time. Geological mapping has brought to light many relationships of the various rock units within the Precambrian, whilst radiometric age determinations, carried out recently by workers at the Department of Geophysics, Australian National University, have added new data on the absolute ages of some rock units. This work is being continued and will no doubt cause considerable alterations to the chart.

At our present state of knowledge, the division of the Precambrian into Archaean and Proterozoic fits a very significant break in Western Australia. The Proterozoic has been divided into three major subdivisions—Lower, Middle and Upper—and the Geological Survey has tentatively adopted the time boundaries as used by the Geological Survey of Canada (Leech and others, 1963).

On the chart, where possible, the different units are referred to by rock unit names, and they are grouped in seven geographic areas.

The proposed age of any unit has been selected either on the results of an age determination or because of a correlation with a dated rock in another area. A probable range of time is shown; this does not indicate only the range during which the unit was formed but also the range within which the unit can be fitted to satisfy correlations with other areas. The possible range has also been indicated.

REFERENCE

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Geological Survey Section Index

DIVISION V

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School of Mines, Western Australia Annual Report — 1964

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The Under Secretary for Mines.

I have the honour to submit for the information of the Honourable the Minister for Mines my report for the year 1964. The report refers to Kalgoorlie and to Norseman.

KALGOORLIE.

Enrolments.

The number of students enrolled in 1964 was 329—a decrease of 36 by comparison with the previous year.

Table I gives the individual and class enrolments for 1964 and for the four previous years; Table II, the enrolments in the various subjects; and Table III, the students enrolled for the various courses. Although the total number of students enrolled decreased, the number enrolled for Associateship Courses increased slightly. This tendency will probably continue and the proportion of students enrolled for Associateship or for Certificate Courses appears likely to continue to increase.

Revenue.

The revenue for the year was £6,197 5s. 3d.

The number enrolled this year is about the same as in 1960 and slightly more than in 1961.

Table IV shows how the revenue was made up and Table V the fees paid by the students in the various age groups. No contribution was received from the Chamber of Mines for the Apparatus and Equipment Trust Fund but the Advisory Committee knows of this and it is expected that the grant will be made when required.

Staff.

The following Staff changes occurred during the year:—

- Cahill, W. J. V.; Registrar; 17/8/64—Appointed.
- Crew, R. J.; Laboratory Assistant; 3/4/64—Resigned.
- Edelman, S.; Senior Lecturer; 4/12/64—Retired.
- Foxton, A. J.; Cadet; 7/9/64—Appointed.
- Hartigan, M. M.; Librarian; 3/3/64—Appointed.
- King, R. M.; Cadet; 4/9/64—Resigned.
- Lewis, J. T.; Lecturer (Norseman); 7/2/65—Resigned.
- McKenzie, J. H.; Laboratory Assistant; 14/2/64—Resigned.
- Mason, C. S.; Registrar; 17/2/64—Transferred.
- Moriarty, M. E.; Laboratory Assistant; 22/6/64—Appointed.
- Moriarty, M. T.; Laboratory Assistant; 1/7/64—Appointed.
- Reece, G. D.; Workshop Technician; 12/11/64—Resigned.
- Wallis, F. A.; Lecturer; 31/12/64—Resigned.
- Wallis, H. W.; Cadet; 4/12/64—Resigned.

Mr. Edelman joined the Staff of the School in February, 1934, and therefore served the School for a period of 30 academic years. During this time he taught a large number of students and saw many changes in the School. The mid 1930's were busy times on the Goldfields, and enrolments at the School rose in 1936 to 629, which is the largest number of students ever enrolled at the School. Mr. Edelman saw a second period of high enrolments just after World War II when 546 students were enrolled in 1947. Mr. Edelman was well regarded by past and present students and also by members of the School Staff. He left Kalgoorlie in December and will make his home in Perth.

Mr. Wallis joined the Staff of the School in January, 1961. He had then had some years of teaching experience with the Technical Education Division and many years of experience as an electrical worker in the mining industry. He was an Associate of the School. He resigned to accept a position in the Metropolitan Area and to make his home in Perth.

Mr. Lewis joined the Staff of the School at Norseman in February, 1960. He taught a variety of subjects at Norseman, but his main interest was in electrical engineering. Mr. Lewis was an electrical tradesman and had completed an evening Diploma Course at Perth Technical College. He was a keen teacher with a likeable personality and served the School well at Norseman. He resigned to accept a position in the Metropolitan Area.

Courses of Study.

Only very minor changes were made to the Courses, which remained much as they were in 1963. The Associateship Courses were re-arranged to provide for two years of full time study followed by two years of part time study for each Course. It was felt that whenever possible some full time study should be done by all Associateship Course students. This would enable the students to devote more time to study and would also reduce the time taken to complete the Course. Notwithstanding this arrangement the Courses can still be completed by all part time study.

Annual and Supplementary Examinations.

The results of the Annual Examinations are summarised in Tables VI and VII, which are based on class enrolments and on individual enrolments respectively. Generally, the figures are similar to those for previous years. As often happens, the figures for Norseman are better than those for Kalgoorlie.

The results for individual subjects are given in Appendix 1.

Scholarships and Prizes.

Two students held Mines Department Scholarships—one an Entrance and the other a Senior Scholarship.

L. J. Molloy, who held an Entrance Scholarship, was enrolled for the "Q" subjects and completed a satisfactory year's work. The other student, who held a Senior Scholarship, elected at the end of the year to continue as part time student and to resign his Scholarship.

Twelve students held Chamber of Mines Scholarships and all completed a satisfactory year's work. Three students completed the Courses for which they were enrolled, and in all 18 students have now completed Courses as Chamber of Mines Scholarship holders.

The usual awards were made at the end of the year and are listed in Appendix 2.

B. J. Fraser, who held a Chamber of Mines Scholarship, was awarded an A.E.I. Overseas Fellowship at the end of the year and will leave for England early in 1965, in which year there will be three students in England who have held or who are holding A.E.I. Overseas Fellowships—G. A. Buckett, W. E. Baldwin and B. J. Fraser.

Diplomas and Certificates.

During the year 20 Associateship Diplomas and 23 Certificates were granted and 4 Technician Courses were completed. These numbers are higher than those for recent years, but do include some Diplomas and Certificates for Courses completed in the previous year for which immediate application had not been made. Details are given in Table VIII.

Diplomas, Certificates, and Prizes were as usual presented by the Minister for Mines, the Honourable A. F. Griffith. The function was held in the Boulder Town Hall on the evening of Wednesday, May 27, and was well attended. In his address the Minister congratulated each of the students receiving an award and expressed the wish that these students would become the future leaders not only in the gold mining industry, but in other industries directly or indirectly associated with mining. He urged every young man to take advantage of the opportunities which the School offered. The Minister referred to recent developments in the mining industry and in particular to those in connection with the search for oil. The President of the Student's Association, Mr. J. J. Miller, thanked the Minister for coming to Kalgoorlie to make the presentations. Two films were shown—"The Mineral Wealth of Western Australia" and "Ord Irrigation." The first of these films, which was produced by the Department of Industrial Development showed some of the major mining activities and indicated how industry followed development of the ore deposits. The second film showed the construction of the Diversion Weir and Irrigation Channels at Kununurra and also the various crops which are being grown under irrigation there.

Library.

Miss M. Hartigan, a graduate of the University of Western Australia and a qualified Librarian, commenced duty as School Librarian in March, and progress in the Library again became possible. During part of 1963 and the early part of 1964 the School did not have a Librarian.

During the year students have borrowed from the Library and have made increasing use of the reading room for study purposes. Mine staff have also made use of the Library—particularly the journals and reference material. Progress has been made with the cataloguing and binding of back numbers of journals, and current cataloguing and journal indexing are up to date. Library Bulletins and Book Lists have been issued regularly and posted to those on the library mailing list. Co-operation with the State Library and with other Libraries has continued. Progress has been made with the organisation of the Library, but in addition to current work, quite a lot of detailed work is still required to bring the library into a satisfactory condition.

The School Library now contains 9,030 catalogued items and 871 were added during the year.

Services to the Public.

The School continued to provide the usual services to the public in addition to its teaching activities. The number of samples submitted for assay and/or mineral determination decreased by 39, but was still higher than in 1960 and 1961. As usual, most of the samples were submitted for gold assay or for mineral determination. In all 419 samples were received. Details are given in Table IX. These samples do not include those submitted to the Metallurgical Laboratory for pay assays or other work, but include only those samples which were examined without cost for prospectors.

Buildings.

The new buildings for the Department of Mathematics and Physics were completed in time for the opening of the School in 1964 and very greatly improved conditions in that Department.

Preparation of plans for the new Mining and Engineering buildings continued during the year and it is expected that the first stage of these buildings will be completed by February, 1966, and that the second stage will follow the completion of the first stage. These buildings will provide much needed additional space in the two Departments concerned, and it is to be hoped that the building programme can be extended to other sections of the School.

Requirements of the School.

These remain as set down in last year's report.

Advisory Committee.

The Committee met on seven occasions and attendances were as follows: Mr. Kay, 1; Mr. Blown, 4; Mr. Field, 6; Mr. Golding, 7; Mr. Hobson, 7; Mr. Havlin, 1 (possible 3); Mr. Lithgow, 3 (possible 4); Mr. Simpson, 6. The Secretary was in attendance at all meetings.

Mr. Havlin resigned from the Committee in May and Mr. Lithgow was appointed to replace him. At its May meeting the Committee recorded its appreciation of Mr. Havlin's interest in the School.

During the year equipment to the value of £906 was approved for purchase.

Kalgoorlie Metallurgical Laboratory.

Seven reports of investigations and 406 Certificates were issued during the year. Of the seven reports, one had reference to gold, one to iron, two to tin-tantalum, two to copper, and one to non-metallics. The Senior Research Metallurgist continued as a member of the Chamber of Mines Metallurgical Committee and the Laboratory Staff answered many enquiries for metallurgical information. The year's work is summarised in Table X and more detailed information is given by the Senior Research Metallurgist in Appendix 3.

Student's Association.

The President of the Association was Mr. J. J. Miller, who completed the Associateship Course in Engineering at the end of the year. The usual functions were held during the year and were all quite successful. The Ball was well attended and a donation of £202 was made to the Special Education Centre in Boulder. The Association's hockey team won the Eastern Goldfields "A" Grade competition.

NORSEMAN.

Enrolments.

The number of students enrolled was 59—a decrease of 9 by comparison with the previous year. Table I sets out the individual and class enrolments during the year and during the four previous years; Table II, the enrolments in the various classes; and Table III, the enrolments in the various Courses. Table III shows that a smaller number of students were enrolled for set courses than in previous years.

Revenue.

The revenue was £228 3s. which came mainly from Class Fees.

Staff.

At the end of the year Mr. J. T. Lewis resigned to accept a position in the metropolitan area. Appreciation of Mr. Lewis' work at Norseman has been recorded in an earlier section of this report.

Cadet Rasmussen completed his cadetship at the School and left the district at the end of the year.

Six part-time instructors were employed.

Examinations.

The results of the Annual Examinations are summarised in Tables VI and VII—Table VI is based on class enrolments and Table VII on individual enrolments. The results for Norseman were very good and, as is generally so, were better than those for Kalgoorlie. The loss of students during the year was less than at Kalgoorlie.

The results for individual subjects are given in Appendix 1.

Scholarships and Prizes.

The Reg Dowson Scholarships for 1964 were awarded to K. A. Sweet and to D. A. Perkin. Of the two students awarded Reg Dowson Scholarships in 1963, one completed a fair year's work and the other a good year's work. No other awards were made to Norseman students.

Buildings.

Very little was done to the buildings, but these are in a satisfactory condition.

Advisory Committee.

The Advisory Committee met twice during the year with Mr. Dutton as Chairman.

ACKNOWLEDGMENTS.

The co-operation and assistance of all members of the staff is gratefully acknowledged. Much assistance is given to students and others during the year in a variety of ways. The statistical information for this report has been compiled by the Registrar and office staff in Kalgoorlie and by the Registrar at Norseman. Assistance and co-operation from Advisory Committees, Mining Companies, Head Office Staff and all sections of the Mines Department, other Government Departments, the "Kalgoorlie Miner" and the Australian Broadcasting Commission in Kalgoorlie is also gratefully acknowledged.

R. A. HOBSON,
Director, School of Mines.

13th April, 1965.

TABLE I.
ENROLMENTS.
1960-1964.

Year	Kalgoorlie		Norseman	
	Individual	Class	Individual	Class
1960	332	967	61	146
1961	310	804	65	139
1962	352	945	69	160
1963	365	926	68	140
1964	329	830	59	128

TABLE II.
CLASS ENROLMENTS.
1964.

Subject	Kalgoorlie		Norseman	
	First Term	Second Term	First Term	Second Term
Chemistry P	23	14	....	....
Chemistry Q	28	26	5	5
Chemistry 1	11	9	....	....
Chemistry 2	9	8	....	....
Analytical Chemistry 1	4	4	....	....
Analytical Chemistry 2	2	2	....	....
Chemical Metallurgy 1	....	....	....	....
Chemical Metallurgy 2	3	3	....	....
Mineral Dressing 1	12	10	....	....
Mineral Dressing 2	2	2	....	....
Mineral Dressing 3	3	3	....	....
Physical Metallurgy	....	....	....	....
Assaying	12	11	....	....
Metallurgy A	....	....	14	12
Mathematics P	36	20	5	4
Mathematics Q	64	43	7	5
Mathematics 1.1	40	30	....	....
Mathematics 1.2	20	16	....	....
Mathematics 1.2 (stat)	6	....	....	....
Mathematics 2	6	6	....	....
Physics Q	28	22	5	3
Physics 1.1	39	35	5	5
Physics 1.2	31	24	....	....
Physics 2	7	7	....	....
Electronics	8	8	....	....
Engineering Drawing P	29	15	8	10
Engineering Drawing Q	38	25	9	10
Engineering Drawing 1	22	13	5	5
Engineering Drawing W	7	4	7	8
Engineering Design	4	4	....	....
Mechanical Engineering 1	12	11	....	....
Mechanical Engineering 2	13	13	....	....
Electrical Engineering 1	11	11	....	....
Electrical Engineering 2.1	5	5	....	....
Electrical Engineering 2.2	7	7	....	....
Structural Engineering 1	11	8	....	....
Structural Engineering 2.1	8	8	....	....
Structural Engineering 2.2	5	5	....	....
Machine Design 1.1	5	5	....	....
Machine Design 1.2	4	3	....	....
Hydraulics	7	7	....	....
Materials of Construction	11	11	....	....
Workshop Practice 1	11	11	....	....
Workshop Practice A	....	....	11	11
Workshop Practice B	....	....	....	....
Workshop Practice C	....	....	....	....
Workshop Practice D	2	2	....	....
Steam Engine Driving	....	....	....	....
Welding A	20	10	10	8
Welding B	7	6	5	6
Internal Combustion Engines	10	9	....	....
Geology Q	22	20	4	4
Geology 1.1	14	13	....	....
Geology 1.2	5	4	....	....
Geology 2.1	....	....	....	....
Geology 2.2	1	1	....	....
Geology 2.3	6	6	....	....
Geology 3.1	3	3	....	....
Geology 3.3	2	2	....	....
Mining 1	8	8	....	....
Mining 2.1	7	6	6	6
Mining 2.2	1	1	....	....
Mining 3	5	5	....	....
Mining 3 (section B)	....	1	....	....
Mine Ventilation	1	1	....	....
Surveying 1	17	17	....	....
Surveying 2.1	5	5	3	3
Surveying 2.2	9	6	4	4
Mining A	11	7	....	....
English P	18	10	....	....
English Q	15	11	....	....
English 1	18	16	....	....
Leaving English	18	12	....	....
Mathematics A	....	....	6	6
Mathematics B	....	....	....	....
Physics P	....	....	....	....
Electrical Theory A	....	....	....	....
Electrical Theory B	....	....	....	....
Electrical Theory C	....	....	4	4
Electrical Drawing A	....	....	....	....
Electrical Drawing B	....	....	....	....
Totals	829	651	123	119
Totals 1963 :	931	763	135	112

TABLE III.

NUMBER OF STUDENTS ENROLLED FOR VARIOUS COURSES.

Course	Kalgoorlie 1960	Kalgoorlie 1961	Kalgoorlie 1962	Kalgoorlie 1963	Kalgoorlie 1964	Norseman 1960	Norseman 1961	Norseman 1962	Norseman 1963	Norseman 1964
ASSOCIATESHIP COURSES										
Mining	37	24	27	34	31	2	3	6	4	3
Metallurgy	13	17	15	18	20	....	....	....	....	....
Engineering	49	49	44	37	43	2	2	3	....	....
Mining Geology	15	19	11	9	7	....	....	....	....	....
Total	114	109	97	98	101	4	5	10	4	3
CERTIFICATE COURSES										
Assayer's	3	3	6	10	8	....	....	....	....	....
Mine Surveyor's	25	30	27	37	27	10	13	11	9	9
Mine Manager's	....	4	3	....	....	....	....	....	....	....
Engineering Draughtsman's	4	6	8	33	29	2	2	....	8	....
Electrical Engineering	2	2	....	....	....	1	1	1	....	....
Mechanical Engineering	4	1	1	....	....	....	1	....	....	....
Total	38	46	45	80	64	13	17	12	17	9
TECHNICIAN COURSES										
Engine Operation and Maintenance	2	1	1	....	....	6	17	12	2	....
Workshop Foreman's	7	6	2	....	....	8	3	6	....	....
Welding	10	16	24	17	19	5	4	6	7	6
Workshop (Mechanical)	....	....	....	....	1	....	....	....	12	1
Workshop (Electrical)	....	....	....	2	....	....	....	....	5	....
Mine Manager's (2nd class)	....	....	....	5	8	....	....	....	....	1
Total	19	23	27	24	28	19	24	24	26	8
NO SET COURSE										
Preparatory subjects	47	44	38	27	17	3	3	11	11	....
Qualifying subjects	....	....	22	17	17	....	....	....	....	....
External students	6	3	....	....	2	....	....	....	....	....
Junior and Leaving	12	9	28	32	18	....	....	....	....	....
University	7	4	3	1	1	....	....	....	....	....
Others	89	72	92	86	81	22	16	12	10	39
Total	161	132	183	163	136	25	19	23	21	39
TOTAL FOR YEAR	332	310	352	365	329	61	65	69	68	59

TABLE IV.

REVENUE, 1962-1964.

	Kalgoorlie 1962	Kalgoorlie 1963	Kalgoorlie 1964	Norseman 1962	Norseman 1963	Norseman 1964
Class Fees	1,419 0 0	1,514 4 0	1,730 5 6	....	139 4 6	207 0 6
Registration Fees	97 0 0	82 0 0	....*	....	20 0 0	....*
Lecture Note Fees	62 15 0	64 17 6	60 7 6	....	10 15 0	9 2 6
Laboratory Deposits	115 0 0	150 0 0	110 0 0	....	....	8 0 0
Supplementary Examinations	37 0 0	42 0 0	50 0 0	....	6 0 0	4 0 0
Students' Association	149 10 0	219 10 0	218 15 0	....	....	....
Apparatus and Equipment Trust Fund	....	1,000 0 0	....	....	....	....
Metallurgical Laboratory Trust Fund	1,268 14 0	1,050 18 0	940 17 0	....	....	....
Commonwealth Grants—Research Laboratory—Trust Fund	2,703 0 0	2,700 0 0	2,851 10 0	....	....	....
Mine Managers and Underground Supervisors	47 5 0	50 16 6	53 11 0	....	....	....
Sundries	132 0 7	66 9 0	181 19 3	....	....	....
Total	£6,031 4 7	£6,940 15 0	£6,197 5 3	£237 0 0	£175 19 6	£228 3 0

* Registration fees discontinued

TABLE V.

NUMBERS OF STUDENTS PAYING FEES.

1962-1964.

Group No.	Description	Kalgoorlie 1962 Total	Kalgoorlie 1963 Total	Kalgoorlie 1964 Full Time	Kalgoorlie 1964 Part Time	Kalgoorlie 1964 External	Kalgoorlie 1964 Total	Norseman 1962 Total	Norseman 1963 Total	Norseman 1964 Full Time	Norseman 1964 Part Time	Norseman 1964 External	Norseman 1964 Total
1	Students under 18. Class fees, deposits, lecture notes fee, Students' Association	100	104	3	83	....	86	25	28	....	24	....	24
2	Students 18–20. Class fees and other fees as for Group 1	97	100	18	58	....	76	19	20	....	19	....	19
3	Students 21 and over. Class fees and other fees as for Group 1	120	129	8	137	2	147	24	20	....	14	....	14
4	Returned Servicemen. Exempt Class fees	27	22	....	9	....	9	....	....	....	1	....	1
5	Staff. Exempt class fees	6	9	2	7	....	9	1	....	....	1	....	1
6	Scholarship Holders. Exempt class fees	2	1	2	....	....	2	....	....	....	....	....	....
		352	365	....	....	....	329	69	68	....	....	....	59

TABLE VI.

RESULTS OF ANNUAL AND OF SUPPLEMENTARY EXAMINATIONS BASED ON CLASS ENROLMENTS, 1960-1964.

	Kalgoorlie					Norseman				
	1960	1961	1962	1963	1964	1960	1961	1962	1963	1964
Class Enrolments = A	939	804	945	931	827	146	139	160	140	115
Number of entries for Annual Examinations = B	596	544	609	633	581	123	96	118	96	97
B/A per cent.	63	68	64	68	70	84	70	74	69	84
Number of passes at Annual Examinations as a per cent. of A	54	51	49	49	53	65	48	51	54	75
Number of passes at Annual Examinations as a per cent. of B	85	76	75	71	75	77	70	69	79	89
Number of passes at Annual Examinations and Supplementary Examinations as a per cent. of A	55	53	52	52	57	66	54	53	56	75
Number of passes at Annual Examinations and Supplementary Examinations as a per cent. of B	87	79	81	76	81	78	78	71	81	89

TABLE VII.

STUDENTS SITTING FOR ANNUAL EXAMINATIONS. 1962-1964.

Course	Kalgoorlie						Norseman					
	1962		1963		1964		1962		1963		1964	
	number enrolled	percent. sitting	number enrolled	percent. sitting	number enrolled	percent. sitting	number enrolled	percent. sitting	number enrolled	percent. sitting	number enrolled	percent. sitting
Associateship	95	93	98	95	101	88	10	100	4	100	3	67
Certificate	45	78	80	66	65	78	12	67	17	88	9	100
Technician	27	88	24	71	28	61	24	96	26	85	8	87
No Set Course	182	49	163	46	135	50	23	52	21	52	39	89
	349	67	365	66	329	68	69	77	68	76	59	81

TABLE VIII.

Courses Completed—1960-1964. Kalgoorlie and Norseman.

	1960	1961	1962	1963	1964
Associateship Courses—					
Mining	3	2	1	3	10
Metallurgy	5	5	2	1	2
Engineering	4	10	3	2	8
Mining Geology....	....	....	4	1	....
	12	17	10	7	20
Certificate Courses—					
Assayer's	2	1	6	1	6
Mine Surveyor's	....	11	6	5	3
Mine Manager's....	1	1	1	2	4
Engineering Draughtsman's	2	2	2	4	8
Electrical Engineering	3	1	1	....	1
Mechanical Engineering	4	....	1	....	1
	12	16	17	12	23
Technician Courses—					
Engine Operation and Maintenance	2	1	1	1	....
Workshop Foreman's	1	1	1	....	1
Welding	2	1	....	1	3
Workshop Practice (Mechanical)	....	....	....	....	....
Workshop Practice (Electrical)	....	....	....	....	....
Mine Manager's (2nd Class)	....	....	....	....	1
	5	3	2	2	5

TABLE IX.

Work Done on Samples Received from Prospectors and Others, Kalgoorlie.

	1960	1961	1962	1963	1964
Assay—gold	263	177	325	239	261
Assay—gold and other constituents	1	2	11	15	4
Assay—metals other than gold....	35	23	46	57	20
Assay plus mineral determination	3	16	11	....	11
Mineral examination	94	117	138	108	100
Rejected or transferred to Metallurgical Laboratory pay	8	6	30	39	23
	404	341	561	458	419

TABLE X.

Kalgoorlie Metallurgical Laboratory. Summary of Work.

	1960	1961	1962	1963	1964
Investigations outstanding (January 1)	3	2	6	5	6
Investigations asked for (731-734 inclusive)	....	7	5	5	4
	3	9	11	10	10
Investigations completed	1	3	5	3	7
Investigations outstanding (December 31)	2	6	5	6	3
Investigations cancelled	....	....	1	1	....
	3	9	11	10	10
Certificates issued (assays, analyses, etc.)	395	469	391	414	406

School of Mines of Western Australia.

APPENDIX 1

Annual Examinations. 1964.

Pass List. Kalgoorlie.

Passes are in order of merit.
* denotes year fee scholarship.
Brackets denote equal marks.

Chemistry P.

Credit:

*Nicholson, R. E.

Pass:

Lewis, W. F.
Foxton, A. J.
Edmonds, G. S.
{Barron, T. D.
{Burns, J. T.
{Dorotich, E. W.
Mackay, I. D.
Stewart, R. E. J.

Chemistry Q.

Pass:

Stokes, M. C.
Haule, E. F.
{Murphy, A. J.
{Muze, K. A.
May, A. J.
Forrest, A.
Wallis, H. W.
Rear, B. J.
Waldron, E. H. J.
Leslie, W. E.
Phillips, B. M.
Moriarty, M. T.
Wyatt, W. A.
Hawker, B. C.

Supp. Exam. Granted:
Fiegert, J.
Walker, M. C.

Chemistry 1.
Pass:
Tillotson, D. L.
Ridley, R. H.
Renton, K. J.
Supp. Exam. Granted:
Dombrose, E. J.
Lethlean, W. R.
Smurthwaite, A. J. N.

Chemistry 2.
Credit:
*Absolon, V. J.
Tichelaar, P. D.
Pass:
Head, D. J.
Faulkner, D. A.
Botica, G. G.

Analytical Chemistry 1.
Credit:
*Tichelaar, P. D.
Botica, G. G.
Pass:
Faulkner, D. A.
Brinsden, W. K.

Analytical Chemistry 2.
Credit:
*Head, D. J.
Absolon, V. J.

Chemical Metallurgy 2.
Pass:
Gray, D.
Willcocks, P. W.

Mineral Dressing 1.
Credit:
*Tichelaar, P. D.
Pass:
Brinsden, W. K.
Renton, K. J.
Livingstone, G.
Fiegert, J.
Dombrose, E. J.
Mykytiuk, A.
Muze, K. A.

Mineral Dressing 2.
Pass:
Wills, M. F.
Faulkner, D. A.

Mineral Dressing 3.
Pass:
Black, N. C.
Willcocks, P. W.
Gray, D.

Assaying.
Credit:
*Tichelaar, P. D.
Renton, K. J.
Pass:
Brinsden, W. K.
Murphy, A. J.
McGushin, P. J.
Morel, F. R.
Dombrose, E. J.
Leylands, E. C.
Mykytiuk, A.
Banks, F. R.
Powell, P.

Mathematics P.
Pass:
MacDonald, A.
Edwards, R. J.
Healy, R. W.
Dorotich, E. W.
MacKenzie, G. R.
Edmonds, G. S.
Ritcher, H. F.
Hodge, F.

Mathematics Q.
Credit:
*McKay, A. A.
Pass:
{Abatemateo, G.
{Chamberlain, E. H. N.
Haule, E. F.
Rear, B. J.
Curran, B. G.
Moon, J.
Waldron, E. H. J.
{Rojo, K. H.
{Smurthwaite, A. J. N.
Boothman, C.
Cowin, A. B.
Lally, R. M.
{Molloy, L. J.
{Pivac, A. M.
Supp. Exam. Granted:
Baker, R. N.
Foxton, A. J.
Gopal, A.
Kitenge, H. R.

Mathematics 1.1.
Credit:
*Gard, L. A.
May, A. J.
Pass:
Wallis, H. W.
Carroll, G. R.
Mykytiuk, A.
Dombrose, E. J.
Tillotson, D. L.
Forrest, A.
Nolwand, P. J.
Thompson, R. V.
Miller, T. D.
Loxton, I. W.
Supp. Exam. Granted:
Golding, P. D.
Goergenyi, G. J.
Kew, L. J.
Muze, K. A.
Mason, R. E.
Perks, A. C. J.
Phillips, B. M.
Tastula, R. A.
Walker, M. C.
Wills, M. F.

Mathematics 1.2.
Pass:
Carroll, G. R.
Dombrose, J. S.
Cluss, W. W.
{Proctor, J. D.
{Ralph, G. M.
Faulkner, D. A.
Supp. Exam. Granted:
Bussell, L. M.
Nowland, P. J.
Stokes, M. C.

Mathematics 1.2.
Stat. Section.
Pass:
Pervan, V. M.
Crew, R. J.
Supp. Exam. Granted:
Mackay, I. D.
Satapuntu, S.
McGee, A. R.

Mathematics 2.
Pass:
Fong, K. H.
Hobson, J. C.
McRostie, B. L.
Ruvidini, A.
Leslie, W. E.

Physics Q.
Credit:
*McKay, A. A.
Pass:
Haule, E. F.
Livingstone, G.
Molloy, L. J.
Lally, R. M.
Supp. Exam. Granted:
Cowin, A. B.
Hill, A. J.
Kew, L. J.
Rojo, K. H.
Waldron, E. H. J.
Exemption Granted from Practical Work for 1965:
Cowin, A. B.
Hill, A. J.
Kew, L. J.
Rojo, K. H.
Waldron, E. H. J.

Physics 1.1.
Credit:
*May, A. J.
Nowland, P. J.
Pass:
Carroll, G. R.
Phillips, B. M.
Forrest, A.
Bayly, J. G.
Miller, T. D.
Muze, K. A.
{Dombrose, E. J.
{Walker, M. C.
{Tastula, R. A.
{Mason, R. E.
{Powell, P.
Mykytiuk, A.
Golding, P. D.
{Klose, W. F.
{Thompson, R. V.
{Wallis, H. W.
Ward, W. S.
{Foxton, A. J.
{Lethlean, W. R.
Goergenyi, G. J.
Loxton, I. W.
McNally, R. T.
Supp. Exam. Granted:
Perks, A. C. J.

Physics 1.2.
Credit:
*Marshall, D. A.
Tastula, R. A.
Pass:
Absolon, V. J.
May, A. J.
Carroll, G. R.
Muze, K. A.
Bussell, L. M.
Dodge, G. J.
Wallis, H. W.
{Fong, K. H.
{Griffin, R. J.
{Cluss, W. W.
{Walker, M. C.
Powell, P.
McNally, R. T.
Loxton, I. W.
Supp. Exam. Granted:
Nowland, P. J.

Exemption Granted from Practical Work for 1965:
Nowland, P. J.

Physics 2.
Credit:
*Ralph, G. M.
Pass:
Fong, K. H.
Procter, J. D.
McIntyre, A. T.
Kelly, J. P.
Supp. Exam. Granted:
Dombrose, J. S.

Electronics.
Credit:
*Hobson, J. C.
Pass:
Fong, K. H.
Procter, J. C.
Supp. Exam Granted:
Dombrose, J. S.
Griffin, R. J.
Leslie, W. E.

Engineering Drawing P.
Credit:
*Lewis, W. F.
Wearne, J. M.
{Shugg, P. J.
{Stearne, M.
{Abatematteo, G.
{Haule, E. F.
{Hocking, S.
Waldron, E. H. J.
Pass:
Mykytiuk, A.
Phillips, K. J.
Devine, W. S.
Hodge, F.
Erbe, J. D.

Engineering Drawing Q.
Credit:
*Nicholson, R. E.
Shugg, P. J.
Nowland, P. J.
Pass:
McCahon, J. A.
MacDonald, A.
Lethlean, K.
Richter, H. F.
Healy, R. W.
McLennan, R. J.
Smith, D. L.
Richter, H. D.
Barron, T. D.
Taylor, D. J.
Molloy, L. J.
Magnus, E. R.
Phillips, K. J.
Fradd, J.
Tichelaar, P. D.

Engineering Drawing 1.
Credit:
*Letts, I. R.
May, A. J.
Kelly, F. J. R.
Phillips, B. M.
Golding, P. D.
Pass:
Shugg, P. J.
Carroll, G. R.
Hill, A. J.
Tasker, H. E.
Hurley, B. J.
Muze, K. A.
McGushin, P. J.
Powell, P.
Younger, B. A.
Allan, D. C.
Burns, J. T.

Engineering Design.
Credit:
{Gard, L. A.
{Kilderry, T. J.
Pass:
King, R. M.
Fong, K. H.

Mechanical Engineering 1
Credit:
*Schultz, K.
Proctor, J. D.
Pass:
{McGushin, P. J.
{Woolhouse, M. L.
George-Kennedy, R. J.
Hobson, J. C.
Fong, K. H.
{Dombrose, J. S.
{Griffin, R. J.

Mechanical Engineering 2
Credit:
*Fraser, B. J.
Pearson, C. A. L.
Maley, W. S.
Forrest, R. N.
Miller, J. J.
Donovan, R. J.
Pass:
Softley, M. D.
{Karczub, L. M.
{Slocomb, J. H.
Ralph, G. M.
Ghor, A.
Egan, H. P.
McRostie, B. L.

Electrical Engineering 1
Pass:
Ellery, V. E.
Procter, J. D.
Leyland, E. C.
Gillbert, N. B.
Dobson, W. H.
Faulkner, D. A.

Electrical Engineering 2.1
Credit:
*Egan, H. P.
Pass:
Maley, W. S.
Karczub, L. M.
Donovan, R. J.

Electrical Engineering 2.2
Credit:
*Fraser, B. J.
Miller, J. J.
Pass:
Softley, M. D.
{Egan, H. P.
{Forrest, R. N.
Donovan, R. J.
Willis, R. J.

Structural Engineering 1
Credit:
*King, R. M.
Gilbert, N. B.
Pass:
Woolhouse, M. L.
George-Kennedy, R. J.
Proctor, J. D.
McGushin, P. J.

Structural Engineering 2.1
Credit:
*Egan, H. P.
Kelly, J. P.
Marshall, D. A.
Pass:
Pearson, C. A. L.
Cumming, G. M.
McRostie, B. L.

Structural Engineering 2.2
Credit:
*Fraser, B. J.
{Slocomb, J. H.
{Softley, M. D.
Willis, R. J.
Pass:
Egan, H. P.
Ghor, A.

Machine Design 1.1.
Credit:
*King, R. M.
Woolhouse, M. L.
Procter, J. D.
Pass:
Griffin, R. J.
Dombrose, J. S.

Machine Design 1.2.
Credit:
*Marshall, D. A.

Hydraulics.
Credit:
*Woolhouse, M. L.
Miller, J. J.
Kelly, J. P.
Pass:
Procter, J. D.
Griffin, R. J.
Dombrose, J. S.
Fong, K. H.

Materials of Construction.
Credit:
*Carroll, G. R.
Pass:
Wallis, H. W.
Nowland, P. J.
Bayly, J. G.
Cluss, W. W.
Miller, T. D.
Forrest, A.
Erbe, J. D.
May, A. J.
Foxton, A. J.
Walker, M. C.

Workshop Practice 1.
Pass:
Gilbert, N. B.
King, R. M.
Carroll, G. R.
Bostelman, L. E.
Kelly, J. P.
Wallis, H. W.
Bussell, L. M.
Forrest, A.
May, A. J.
Drazic, K. W.
Nowland, P. J.

Welding A.
Credit:
*Higgs, G. A.
Pass:
Healy, R. W.
Condren, B. D.
Smith, K. L.
Gopal, A.
Alexander, W. J.
Wray, R. A.
Exemption Granted from Practical Work for 1965:
Brehaut, B. A.
Fletcher, R.
Nettle, G.

Welding B.
Pass:
Curnow, W. D.
Exemption Granted from Practical Work for 1965:
Edwards, M. G.
Godfrey, G. R.
Humphrey, J.

Internal Combustion Engines.
Credit:
*Bostelman L. E.
Drazic, K. W.
Pass:
Olden, M.
Gericevich, N.
Markovich, A. M.
Bailey, J. F.
Close, R.
Norwood, P.

Geology Q.
Credit.
*Dombrose, E. J.
Pass:
Molloy, L. J.
Mykytiuk, A.
Phillips, K. J.
Lethlean, W. R.
Rear, B. J.
Tastula, R. A.
Symon, B. J.
{Taaffe, L. D.
{Haule, E. F.
{Daws, D. C.
{Rymer, H. A.
Byrnes, F. E.
Supp. Exam. Granted:
Livingstone, G.
Mainwaring, D. D.
Waldron, E. H. J.

Geology 1.1.
Credit:
*Patterson, B. S.
Brinsden, W. K.
Dombrose, E. J.
Mykytiuk, A.
Pass:
Tonkin, D.
Ridley, R. H.
Chamberlain, E. H. N.
Goergenyi, G. J.
Fisher, J. A. S.
Crew, R. J.
Allan, D. C.

Geology, 1.2.
Pass:
Patterson, B. S.
McGee, A. R.
Exemption Granted from Practical Work for 1965:
Goergenyi, G. J.
Supp. Exam. Granted;
Goergenyi, G. J.
Satapuntu, S.

Geology 2.2.
Pass:
McGushin, P. J.

Geology 2.3.
Pass:
Black, N. C.
Lewis, R. P. J.
Gray, D. J.
Willcocks, P. W.
Head, D. J.
Supp. Exam. Granted:
Klose, W. F.

Geology 3.1.
Pass:
Shugg, P. J.
Fogarty, J. M.
Sands, D. J.

Geology 3.3.
Pass:
Fogarty, J. M.
Sands, D. J.

Mining 1.
Pass:
Phillips, B. M.
Tennant, T.
Muze, K. A.
Crew, R. J.
Gould, R. J.
Supp. Exam. Granted:
Allan, D. C.

Mining 2.1.
Credit:
*Fradd, J. F.
Ritchie, H. G.
Phillips, B. M.
Pass:
McGee, A. R.
Supp. Exam. Granted:
Lindfield, N. W.

Mining 2.2.
Pass:
Ritchie, H. G.

Mining 3.
Credit:
*Lubbock, F. N.
Letts, I. R.
Dodge, G. J.
McGushin, P. J.

Mine Ventilation.
Credit:
*George-Kennedy, R. J.

Surveying 1.
Pass:
Tennant, T.
Procter, J. D.
Kilderry, T. J.
Crew, R. J.
Byrnes, F. E.
Dombrose, J. S.
Allan, D. C.
Rymer, H. A.
Exemption Granted from Attendance at Lectures for 1965:
Cumming, G. M.
Exemption Granted from Practical Work for 1965:
Fisher, J. A. S.
Griffin, R. J.
Supp. Exam. Granted for Paper "B":
Fisher, J. A. S.
Griffin, R. J.

Surveying 2.1.
Credit:
*Fradd, J. F.
Pass:
Lindfield, N. W.
Exemption Granted from Practical Work for 1965:
Satapuntu, S.
Taaffe, L. D.
Supp. Exam. Granted in Paper "B":
Satapuntu, S.
Taaffe, L. D.

Surveying 2.2.
Credit:
*Lindfield, N. W.
Shugg, P. J.
Attrill, D. M.
Pass:
Fradd, J. F.
Hurley, B. J.
Lubbock, F. N.
Magnus, E. R.

Mining A.
Pass:
Lucas, G. L.
Kingswood, J. T.
Devine, W. S.

English P.
Credit:
*Miller, T. D.
Pass:
Hodge, F.
Moriarty, M. T.
Chamberlain, E. H. N.
Richter, H. D.
Abatematteo, G.
Moriarty, M. E.
Supp. Exam. Granted:
Devine, W. S.
Richter, H. F.

English Q.
Credit:
*Cooper, C.
Pass:
Irvine, M. I.
Molloy, L. J.
May, A. J.
{Nicholson, R. E.
{Davies, D. R.
Haule, E. F.
Sullivan, I. G.
Kilderry, T. J.
Beaney, M. G.
{Mainwaring, D. D.
{Slocomb, J. H.
{Waldron, E. H. J.
Thornton, B.
Fisher, J. A. S.
Cocking, S. J.
Supp. Exam. Granted:
Foxton, M. J.

English 1.
Credit:
*Forrest, R. N.
Pass:
Ruvidini, A.
{Miller, J. J.
{Morel, F. R.
Marshall, D. A.
Loxton, I. W.
Maley, W. S.
Ghor, A.
Hooker, N. R.
Phillips, B. M.
Head, D. J.
Willis, R. J.
Karczub, L. M.
Supp. Exam. Granted:
Faulkner, D. A.

Engineering Drawing W.
Credit:
*Bostelman, L. E.
Pass:
Higgs, G. A.
Fry, B. G.
Neve, L. E.

Mining B.
Pass:
Rymer, H. A.

NORSEMAN.

Chemistry Q.
Credit:
*Rasmussen, G. L.
Cameron, G. C.
Pass:
{Kerr, P. H.
{Lea, E. J.

Metallurgy A.
Credit:
*Temple, E. D.
Murphy, F. J.
Pass:
Murphy, R. J.
Fleay, J. R.
Freeman, P. G.
Jones, E. J.
Giles, T. E.
Jones, H. B.
Starcevich, R. F.
Darch, R. J.
Jenkins, L. K.

Mathematics P.
Credit:
*Stewart, D. A.
Pass:
Horan, R. J.

Mathematics Q.
Pass:
Murphy, F. J.
Stewart, B. A.
O'Connor, G.

Physics Q.
Pass:
Stewart, D. A.
Supp. Exam. Granted:
Churchill, W. G.
Denison, J. L.
Exemption Granted from Practical Work for 1965:
Churchill, W. G.
Denison, J. L.

Physics 1.1.
Pass:
Rasmussen, G. L.
Kerr, P. H.
Lea, R. J.

Engineering Drawing P.
Credit:
*Law, L. L.
Pass:
Morgan, T. A.
Van Gelderen, I.
Ismail, K. G. R.
Graziani, P.
Horan, R. J.

Engineering Drawing Q.
Credit:
*Farr, R. G.
Rasmussen, G. L.
Pass:
Fleay, J. R.
Perkin, D. A.
Green, T. D.
Jones, H. B.

Engineering Drawing I.
Credit:
*Skinner, K. J.
Pass:
Farr, R. G.

Workshop Practice A.
Pass:
{Philippe, G. R.
{Underwood, J. W.
Murphy, R. J.
Jones, H. B.
Watson, R. M.
{Foote, S. P.
{Green, T. D.
{Jenkins, L. K.
Perkin, D. A.
Exemption Granted from Attendance at Lectures for 1965:
Darch, R. J.

Welding A.
Credit:
*Perkin, D. A.
Pass:
Horan, R. J.
Freeman, P. G.
Monks, B. R.
Foote, G. J. P.
Exemption Granted from Practical Work for 1965:
Laughton, B. W.
Law, L. L.
Ticehurst, K. J.

Welding B.
Pass:
Starcevich, R. F.
Giles, T. E..
Foote, S. P.
Green, T. D.
Exemption Granted from Practical Work for 1965:
Sawyer, D. J.

Geology Q.
Pass:
Eyre, R.
Sweet, K.
O'Connor, G.
Churchill, W.

Mining 2.1.
Credit:
*Swain, G. B.
Pass:
O'Connor, G.
Cook, G. J. S.
Sweet, K. A.
Stewart, B. A.
Daly, P. R.

Surveying 2.1.
Pass:
Cook, G. J. S.
Daly, P. R.
Swain, G. B.

Surveying 2.2.
Credit:
*Swain, G. B.
Cook, G. J. S.
Pass:
Denison, J. L.

Mathematics A.
Credit:
*Farr, R. G.
Pass:
Fleay, J. R.
Morgan, T. A.
Starcevich. R. F.

Electrical Theory C.
Credit:
*Rasmussen, G. L.
Pass:
Rose, F. W.
Murphy, R. J.

Engineering Drawing W.
Credit:
*Murphy, F. J.
Temple, E. D.
Pass:
Underwood, J. W.
Giles, K. W.
Watson, R.
Jones, E. J.
Monks, B. R.

SUPPLEMENTARY EXAMINATIONS.

FEBRUARY, 1964.

The following students passed in the subjects listed below:

* denotes deferred final taken in February, 1964.

KALGOORLIE.

Chemistry P.
Moon, J.
Chemistry Q.
Goergenyi, G.
Mineral Dressing 2.
*Klose, W. F.
Chemical Metallurgy 1.
*Klose, W. F.
Physical Metallurgy 1.
*Klose, W. F.
Mathematics Q.
Erbe, J. D.
Livingstone, G.
Mathematics 2.
Donovan, R. J.
Marshall, D. A.
Physics Q.
Muze, K. A.
Physics 1.1.
Cluss, W. W.
George-Kennedy, R. J.
Griffin, R. J.
Physics 2.
McRostie, B. L.
Electrical Engineering 1.
Argus, J. C.
Chamberlain, H. I.
Cruickshank, A. C.
Electrical Engineering 2.1.
Softley, M. D.
Geology Q.
Timewell, R. J.
Geology 2.2.
Dykstra, F. D.
Murphy, A. J.
Mining 1.
Turner, B. C.
Mining 3.
*Hooker, N. R.
Surveying 2.1.
Sands, D. J.
English Q.
Kayombo, F. X.
Sullivan, I. G.

NORSEMAN.

Steam Engine Driving.
Prime, G. G.
Mining 1.
O'Connor, G.

SCHOOL OF MINES OF WESTERN AUSTRALIA.

APPENDIX 2.

SCHOLARSHIPS AND PRIZES 1964.

MINES DEPARTMENT.
Entrance Scholarship: L. J. Molloy.
Senior Scholarship: D. G. Brioschi.

CHAMBER OF MINES.
Mining: B. M. Phillips.
Metallurgy: P. D. Tichelaar.
Engineering: J. D. Procter.
Mining Geology: No award.

SCHOOL OF MINES STUDENTS' ASSOCIATION SCHOLARSHIPS.
Mining: R. J. George-Kennedy.
Metallurgy: W. K. Brinsden.
Engineering: D. A. Marshall.
Mining Geology: No award.

INSTITUTE OF MINING SURVEYOR'S PRIZE.
£10 Prize: T. Tennant.
£5 Prize: J. F. Fradd.

SOCIETY OF THE W.A. SCHOOL OF MINES ASSOCIATES' PRIZE.
A. A. McKay.

REG. DOWSON SCHOLARSHIPS.
Group A: K. A. Sweet.
Group B: D. A. Perkin.

ROBERT FALCONER PRIZES.
First Prize: No award.
Second Prize: No award.

C. A. Hendry Prize: No award.

WESLEY LADIES' GUILD.
R. E. Nicholson.

APPENDIX 3.

Kalgoorlie Metallurgical Laboratory.
by
E. Tasker, A.W.A.S.M.(Met), A.M.Aus.I.M.M.
Senior Research Metallurgist.

INTRODUCTION.

Seven reports of investigations and four hundred and six certificates of testing or analyses were issued during the year. Brief descriptions of the investigations are included in the report.

For further information regarding these reports apply to:

The Secretary,
Commonwealth Scientific and Industrial Research Organization,
314 Albert Street,
East Melbourne, C.2.,
Victoria.

from whom copies of the reports can be obtained, usually six months after date of issue.

In addition to the reports issued, three other investigations were approved and test work was in progress.

Numerous enquiries dealing with technical problems of people engaged in mining and other industries were handled during the year. Further work was carried out on various projects for the Metallurgical Committee of the Chamber of Mines of Western Australia.

COMPLETED INVESTIGATIONS.

Report No. 716.

Test work was carried out on a sulphide gold ore from Fimiston, Western Australia, to determine whether flotation concentrate regrinding would be economical.

Report No. 721.

Concentration tests were carried out on a low grade ironstone ore from the Tallering deposit, Western Australia. Relative fine grinding was necessary to liberate the hematite from the gangue (quartz) before suitable concentration could be achieved.

Report No. 725.

Tests were carried out on a low grade cement lime rock from Fremantle, Western Australia. The lime rock was readiliy beneficiated to a suitable grade by flotation using a cationic collector.

Report No. 730.

Test work was carried out to determine a suitable method of recovering cassiterite and yttrotantalite from a middling product from a tin concentrator at Spear Hill, Cooglegong, Western Australia.

Report No. 731.

Test work was carried out on a cassiterite-tantalite concentrate from Greenbushes, Western Australia. High grade concentrates of cassiterite and tantalite were produced.

Report No. 732.

Flotation tests were carried out on samples of oxide copper ore from Ned's Creek via Meekatharra, Western Australia. Copper concentrates of grades acceptable to fertilizer manufacturers were produced.

Report No. 733.

Flotation tests were carried out on samples of oxide copper ore from Thaduna, via Meekatharra, Western Australia. Marketable grade copper concentrates were produced from the ore which contained a large amount of graphitic slate.

INCOMPLETE INVESTIGATIONS.

Report No. 728.

Test work was carried out on up-grading of lime rock from Fremantle, Western Australia. An interim report was issued.

Report No. 729.

Test work was carried out on an auriferous chalcopyrite concentrate from the Paris Gold Mine, Widgiemooltha, Western Australia.

Report No. 734.

Cyanidation tests were being carried out on pyritic concentrates from Pine Creek, Northern Territory.

E. TASKER,
Senior Research Metallurgist.

KALGOORLIE METALLURGICAL LABORATORY

Summary of Year's Work, 1964

Report No.	Owner	State	Locality	Ore Type	Type of Investigation	Confidential Until	Number of Metallurgical Tests	Number of Assays Gold	Number of Assays Other
716	Gold Mines of Kalgoorlie, Fimiston	W.A.	Fimiston	Gold ore	Treatment Tests	9/6/65	48	310	220
721	Western Mining Corp., Kalgoorlie	W.A.	(Mullewa) Tallering	Iron ore	Beneficiation Tests	18/9/64	24	....	200
725	Cockburn Cement Pty. Ltd., Perth	W.A.	Fremantle	Cement Lime-rock	Beneficiation	18/9/64	6	....	38
730	Northern Minerals Syndicate, Perth	W.A.	Cooglegong	Tin-Tantalum	Treatment Tests	17/6/65	30	....	50
731	Vultan Syndicate, Perth	W.A.	Greenbushes....	Tin-Tantalite	Treatment Tests	17/6/65	10	....	45
732	R. Lee, Meekatharra	W.A.	Ned's Creek, via Meekatharra	Oxide copper ore....	Concentration Tests	3/1/65	20	....	100
733	British Metals Corp., Perth	W.A.	Thaduna	Oxide copper ore....	Concentration Tests	3/1/65	28	....	140
....	Certificate Nos. 2513–2537, 2539–2597, 2599–2920	....	....	....	....	....	....	1,108	807
....	Free Assays	....	....	....	....	....	....	273	30
....	School of Mines	....	....	....	....	....	....	2	10
						Totals	166	1,693	1,640

THE FOLLOWING INVESTIGATIONS WERE INCOMPLETE OR PENDING AT 31st DECEMBER, 1964 :—

Report No.	Owner	State	Locality	Ore Type	Type of Investigation	Confidential Until	Number of Metallurgical Tests	Number of Assays Gold	Number of Assays Other
728	Swan Portland Cement Perth	W.A.	Fremantle	Cement Lime-rock	Beneficiation	....	12	....	76
729	Paris Gold Mine, Widgiemooltha	W.A.	Paris	Gold-Copper	Treatment Tests	....	30	100	15
734	Director of Mines, Darwin	N.T.	Pine Creek	Auriferous concentrate	Cyanidation Tests....	....	14	21	52
						Totals	222	1,814	1,783

DIVISION VI

Annual Report of the Inspection of Machinery Branch of the Mines Department for the Year 1964

The Under Secretary for Mines:

For the information of the Hon. Minister for Mines I submit the report of the Deputy Chief Inspector of Machinery in the administration of the Inspection of Machinery Act, 1921-1958, for the year ending 1964.

E. E. BRISBANE,
Chief Inspector of Machinery.

Section 1.

INSPECTION OF BOILERS, MAINTENANCE, ETC.

(See Returns Nos. 1, 2 and 3.)

Under the Act "Boilers" means and includes—

(a) any boiler or vessel in which steam is generated above atmospheric pressure for working any kind of machinery, or for any manufacturing or other like purpose;

(b) any vessel used as a receiver for compressed air or gas, the pressure of which exceeds 30 lb. to the square inch, and having a capacity exceeding five cubic feet; but does not include containers used for transport;

(c) any vessel used under steam pressure as a digester; and

(d) any steam jacketed vessel used under steam for boiling, heating, or disinfection purposes.

It also includes the setting, smoke stack, and all fittings and mountings, steam or other pipes; feed pumps and injectors and other equipment necessary to maintain the safety of the boiler.

Return No. 1.

In this return is recorded the number of boilers of the various types added to our registrations during the year; those of Western Australian origin exceed by 234 the number of pressure vessels imported.

Return No. 2.

This return shows the number of each type, and overall total, in the register of useful boilers. Of the total 2,497 were not in service.

Return No. 3.

This contains a summary of operations for the year. The manufacture of boilers in this State for export has continued at much the same rate with a slight increase compared with 1963. One hundred and four boilers were exported to the Eastern States and two were sent overseas. Imports of boilers, pressure vessels, etc., from the Eastern States have increased approximately 50 per cent. and from outside Australia approximately 15 per cent.

Importations are made up generally of vessels peculiar to an industry and produced by manufacturers specialising in such types or owing to demand and short delivery times, cannot be supplied in W.A. A number of such vessels have been installed in a new bitumen plant, by liquid petroleum gas and ammonia marketers and for refrigeration and air conditioning.

The increased activity in mineral and oil exploration sees the introduction, by the firms engaged in this work, of vessels which are part and parcel of the plants used. Quite a number of autoclaves air receivers and vessels for abattoir processing are included in the imported section.

RETURN No. 1.

Showing the Number of Boilers of Each Type, and Country of Origin of New Registrations for the Year ended 31st December, 1964.

	U.S.A.	United Kingdom	Eastern States	Japan	Western Australia	Unknown Resource	Total
Ret. Multi Stat. Int. Fired	....	....	....	....	128	....	128
Digester	....	....	6	....	2	....	8
Vulcanizer	....	....	22	27	11	....	60
Steam Jacket Vessels	....	....	2	....	21	....	23
Sterilizer	....	....	11	....	90	....	101
Air Receiver	4	5	43	....	107	4	163
Gas Receiver	2	11	34	....	40	....	87
Autoclave	....	....	2	....	8	....	10
Ret. Multi. Stat. Unfired	....	....	....	....	1	....	1
Water Tube	....	....	2	....	....	....	2
Vert. Multi. Stat.	....	....	....	....	2	....	2
Burton Ironer	....	....	1	....	....	....	1
Total	6	16	123	27	410	4	586

RETURN No. 2.

Showing Classification of Various Types of Useful Boilers in Proclaimed Districts on 31st December, 1964. .

Types of Boilers	Districts Worked from Perth	Districts Worked from Kalgoorlie	Total
Lancashire	35	23	58
Cornish	207	60	267
Semi Cornish	14	1	15
Vert. Stationary	402	41	443
Vert. Port.	33	11	44
Vert. Multi Stat.	39	4	43
Vert. Multi Port.	6	1	7
Vert. Pat. Tubular	49	....	49
Loco. Rect. F/Box Stat.	70	20	90
Loco. Rect. F/Box Port.	147	17	164
Loco. Circ. F/Box Port.	87	2	89
Locomotive	77	11	88
Water Tube	552	59	611
Ret. Multi U/Fired Stat.	259	7	266
Ret. Multi S. U/Fired Port.	....	5	5
Ret. Multi Int. Fired Stat.	236	8	244
Sterilisers	690	42	732
Autoclaves	101	2	103
Digesters	314	7	321
Gas Receivers	604	....	604
Air Receivers	2,212	629	2,841
Vulcanisers	458	10	468
Steam Jacketed Vessels	709	15	724
Not Elsewhere Specified	262	5	267
Total Registration Useful Boilers....	7,563	980	8,543
Total Boilers out of use, 31/12/64	1,850	647	2,497

RETURN No. 3.

Showing Operations in Proclaimed Districts during Year ended 31st December, 1964.

Boilers	Districts Worked from Perth	Districts Worked from Kalgoorlie	Total	
			1964	1963
Total number of useful boilers registered	7,563	1,172	8,735	8,297
New Boilers registered during year	586	3	589	508
Boilers inspected thorough	4,808	330	5,138	5,006
Vessels exempt under Act constructed for export thorough	28	....	28	....
Boilers inspected working	905	3	908	970
Boilers condemned during year temporarily	5	....	5	4
Boilers condemned during year permanently	42	....	42	67
Boilers sent to other states during year	104	....	104	94
Boilers sent from other states during year	123	....	123	87
Boilers sent from other countries during year	49	....	49	42
Boilers sent to other countries during year	2	....	2	4
Transferred to other Departments	....	....	....	2
Transferred from other Departments	1	....	1	....
Re-instated	2	....	2	2
Converted	1	....	1	....
Number of notices of repairs issued during year	545	25	570	647
Number of certificates issued including those issued under Section 30 during the year	4,829	330	5,159	4,989

MAINTENANCE AND MISCELLANEOUS.

Maintenance and operation have again been generally satisfactory particularly in large establishments. It is, as has been previously stated, the small plant with a small boiler where most troubles occur. At the risk of becoming boring I must again point out that the majority of the boiler troubles spring from "automatic" boilers where the title is taken literally. This leads to the owner or person in charge of the boiler relying completely on this statement and neglecting the routine checking procedures as laid down by the manufacturer and sound practice, with consequent boiler failure due in most cases to water shortage.

Manufacture of boilers and pressure vessels in W.A. has continued to increase and generally has been of a high standard. This is due to the integrity of the manufacturers, the supervision by this Department, and in a number of cases to advice given by officers of this Department during both design and fabrication stages. All manufacturers have been hindered by shortage of boiler quality steel plate of Australian origin for boilers, refrigeration vessels requiring low temperature qualities even for air receivers. Plate has been imported, at higher cost, and has often been found faulty leading to the discarding of the plate before use or sometimes expensive repairs when the defect is not discovered until fabrication is almost complete.

The number of boilers and pressure vessels shows an increase for 1964 of approximately 250. Most boilers installed now are for the supply of processing steam in industry. The use of boilers to supply steam to prime movers driving machinery is decreasing and is only used now where it is economical to do this prior to using the exhaust steam for processing. The use of compressed air in industry for many purposes maintains the demand for air receivers.

Section 2.

EXPLOSIONS AND INTERESTING DEFECTS.

It is with pleasure that I can report that there was no explosion of any boiler or pressure vessel during 1964. I consider that the following defects and circumstances are of interest and worth reporting in some detail.

A.

This incident relates to a water tube boiler installed in a milk processing factory. Shortage of water occurred resulting in the springing of approximately 20 tubes and leakage at first and second circumferential seams of both drums at the bottom. The water shortage was discovered at the end of the duty boiler attendant's lunch hour. During this hour he had been relieved by another attendant. This boiler is sawdust fired and in addition to conventional three glass water gauges, is fitted with a robot control operating the electric reciprocating feed pump with an alarm for low water.

When enquiries were made after the mishap it was found that the stop valve to the water end of the control chamber was seized in the "open" position. This prevented manual testing of the control and both attendants said it had been like that for three months. They also stated that it had been reported but on further questioning were vague as to whom it had been reported. When tested after the water shortage it was found to operate successfully. Other avenues which could cause water shortage, such as leaking blowdown, or hot well were investigated but appeared normal. Nothing concrete could be gained from our investigations, and it seems that we did not get the whole truth from witnesses. However, the following is the conclusion drawn by the Inspector who made the inquiries—

"I am convinced, after discussing the mishap with the two boiler attendants, that their attitude is that it should be unnecessary to consult the Glass Water Gauges when an automatic control is fitted."

Unfortunately, as I mentioned previously, this type of thinking is all too common both in Boiler Attendants and Owners and can only lead to inconvenient shut downs and repairs, if not more disastrous results.

B.

This case concerns two similar mishaps to two very similar boilers although in different locations. I am treating them together as the circumstances leading to the low water condition and damage therefrom are basically identical.

The boilers involved are internally fired multitubular cylindrical types fitted with fully autoatic controls and exempt under the Inspection of Machinery Act from supervision by certificated boiler attendants.

In both cases shortage of water occurred resulting in overheating and the springing of tubes but in one case the damage was more severe requiring replacement of tubes instead of just re-expanding.

Investigations showed that the control cock on the float control chamber had beeen left in the incorrect position so that while water was trapped in the float chamber the water connection from the boiler was open to blow down. This resulted in a false level in the float control chamber which kept the burner operating while the actual water level in the boiler dropped rapidly until the low water condition eventuated.

Questions posed to the two men supposed to be in charge of the respective boilers revealed neither of the men had any understanding of what they were doing when they operated the control cock on the float chamber. They had been instructed to follow certain procedure by rote. In one case the explanation given was not consistent with the mechanical possibilities; in the other the cock handle had been moved from its correct position on the cock, thus confusing the operator.

These two mishaps point out the necessity for the instruction of the operator to not only cover the actual physical steps in checking the controls but also to give him a basic idea of what is going on when the controls are manipulated.

C.

This vessel concerned in this report is a single shell stainless steel pressure steriliser 14 in. x 14 in. x 24 in. long. It was fitted with an electrically heated pot integral with shell for generating its own steam, and two separate elements clamped to opposite sides to provide heat for drying out the load after sterilisation. The shell at point of attachment of drying elements was 3/16 in. thick.

The vessel was removed from service when it was found to be cracked in the shell where one of the drying elements was attached. At the annual inspection eight months prior to this the Inspector noted—"evidence of overheated patches on sides towards back at position of drying elements". This finally developed into a crack in a circumferential direction approximately 1½ in. long.

A repair was effected by cutting out the damaged section and butt welding in patches. The design was modified doing away with the drying elements clamped to the sides, cutting off and blanking the pot previously containing the steam generating elements and combining both functions in special elements attached to the bottom of the shell of the vessel.

We consider that the cracking was caused by the low heat transfer co-efficient of the stainless steel preventing the transfer of the heat from the drying elements causing local overheating and overstressing resulting in the crack developing.

D.

This case also concerns a stainless steel sterilizing vessel but of the jacketed type. It is a steam heated double shell pressure sterilizer 16 in. diameter x 36 in. long, which had been installed in a country hospital where it had worked continuously for five years. At that stage a hair line crack was detected in the inner near the drain. The vessel was taken out of service and returned to Perth for repairs. Prior to carrying out repairs a hydrostatic test was applied. The Inspector who witnessed this reported as follows—

> "The lagging had been stripped off and the vessel was under hydrostatic test when I arrived. Circumferential crack as reported in the inner shell at bottom approximately 1 in. behind the drain and 2 in. long. Also similar crack revealed at the back end extending from approximately 3 o'clock to 5 o'clock on inner shell in line with inner and outer junction ring.
> *Externally.* Cracking showed in the extension of the inner shell circumferentially between the fillet weld attaching the junction ring to the inner and the circumferential butt weld of inner extension to dished end. This crack appeared to start at the toe of the fillet weld and continue from approximately 12 o'clock to 9 o'clock in a wavy line between the two welds. Small radial cracks also appeared extending from the main crack towards the welded seam of dished end."

Following this report the vessel was dismantled and sections cut out at the last mentioned area.

One large section contained the crack, which has been hammered to open up the cracks, and several smaller pieces were etched and photographed. Inspection shows that most of the cracks appear to start in the section of plate between the two welds but not necessarily at the toe of the fillet weld and some are visible in the section under the junction ring.

After consideration the following possible causes of the cracking seemed likely:—

1. That incorrect material was used for the 3/16 in. inner vessel. All cracks are to this plate.
2. Mishandling of material during manufacture, causing change in metal structure. This could occur if the 3/16 in. plate was hammered severely, as is accepted procedure with copper, to produce the taper from 3/16 in. t. to 12 gge. where the inner shell extension joins the 12 gge. end.
3. Change in the structure of the metal due to excessive heat input during welding of junction ring to inner and inner to dished end.

Samples from the defective section and details as far as known were forwarded to the statutory authority in the State of origin of the vessel with the request for an investigation. This was carried out and the fact that saline solutions had been sterilized in this vessel emerged in the report, which states:—

> The factors contributing most to the failure would be—
>
> (1) The presence of the corrosive Chloride ion per media of the spilt saline solutions.
>
> (2) The accelerating factor of heat in the sterilizer's normal operation.
>
> (3) Internal stresses in sterilizer due to welding associated with any stresses in the stainless steel sheets prior to welding.
>
> (4) Alternating stresses produced during the normal operating sequence of the sterilizer.
>
> Conclusions.
>
> (1) Greater resistance to Chloride ion attack could be accomplished by using A.I.S.I. Type 316 Stainless Steel for the inner chamber of the sterilizer. However, it is felt that hospital staff should be made aware of the dangers of Chloride ion attack when saline solutions are spilt in sterilizers.
>
> (2) The segment of the inner shell in which almost all the cracking occurred should have given equivalent performance to the other segments. As such, it is assumed that this segment was the bottom horizontal portion of the inner shell upon which any spilt saline solution could collect and with resulting corrosion.

Also stated in the foregoing report was that analysis of samples of material revealed that it was up to required specification.

I consider the results of investigations to be inconclusive as there still remain quite a number of unknowns which could have contributed to this failure. It does however, emphasise the damage which is done to stainless steel by heated saline solutions and the care and cleaning necessary to preserve the chemical structure and surface finish of such material.

E.

The boiler involved in this case is a mild steel sectional type but the fault detected and the apparent cause is not peculiar to the type of boiler and could be present in any boiler or pressure vessel where internal inspection is limited or not possible.

Leakage from what appeared to be a crack in the shell was reported. An attempt to discover the extent of the defect was made by grinding out the crack. This revealed that it was approximately 10 in. long in a vertical direction and approximately 2½ in. long at right angles from the lowest point of the original fault. In order to make a repair a section encompassing all the cracks was cut out. This revealed that the line of cracking followed the line of weld of a patch piece which had been butt welded into the shell plate. As far as is known this patch was not inserted in W.A. The method and workmanship involved in the patching were very poor. The patch had been inserted without backing strips and apparently without preparation for welding. The welding lacked penetration varying from ⅛ in. to 1/16 in. and averaging 3/32 in. The plate thickness was ¼ in. Any external evidence of welding had been ground off flush with the parent plate.

Several possible explanations of how this could occur came to mind.

1. The plate was pieced at original construction with manufacturer's knowledge and consent.
2. The plate was pieced at original construction due to a mistake in cutting the plate and this unsatisfactory repair was made to cover up the error without the knowledge of the manufacturer.
3. The repair was made at some time after the completion of manufacture.

In my opinion one of the first two possibilities is most likely and reveals how dependent the inspecting authority and the purchaser are on—

(1) The integrity and knowledge of the manufacturer.

(2) the quality of supervision and insistence on first class work.

(3) The integrity and skill of the men actually carrying out the fabrication.

These factors are necessary in any manufacture but imperative where boilers and pressure vessels are concerned and human life can be at stake.

Section 3.

INSPECTION OF MACHINERY.

(See Returns Nos. 4, 5 and 6.)

At the expiration of the year 50,370 groups of machinery were in the register. This indicates an increase of 2,358 groups in comparison with the figure for the previous year. Lift figures reveal an increase of 30 installations.

RETURN No. 4.

Showing Classification according to Motive Power of Groups of Machinery in Use or likely to be Used by Proclaimed Districts and which were on the Register during the Year ended 31st December, 1964.

——	Districts Worked from Perth	Districts Worked from Kalgoorlie	Totals 1964	Totals 1963
Number of groups driven by Steam Engines	112	373	485	487
Number of Groups driven by Oil Engines	3,312	1,007	4,319	3,835
Number of Groups driven by Other Power	102	199	301	284
Number of Groups driven by Electric Motor....	41,422	3,843	45,265	43,406
Totals	44,948	5,422	50,370	48,012

RETURN No. 5.

Showing Operations in Proclaimed Districts during Year ended 31st December, 1964. (Machinery only.)

——	Districts Worked from Perth	Districts Worked from Kalgoorlie	Totals 1964	Totals 1963
Total Registrations Useful Machinery	44,948	5,422	50,370	48,012
Total Inspections made	27,750	4,386	32,136	33,977
Certificates (Bearing Fees)	6,066	567	6,633	6,879
Notices issued (Machinery Dangerous)	711	21	732	831

RETURN No. 6.

Showing Classification of Lifts on 31st December, 1964.

Types	How Driven	Totals 1964	Totals 1963
Passenger	Electrically Driven	325	303
Goods	Electrically Driven	116	114
Goods	Electric Hydraulic Driven	13	13
Service	Electrically Driven	113	112
Service	Electric Hydraulic Driven	1	1
Escalators	Electrically Driven	33	28
		601	571

ACCIDENTS TO MACHINERY.

Once again this year accidents to cranes make up the majority of this section. As revealed in investigation and the following reports, ignorance of operation and erection together with, in one or two instances, poor design, contributed to damage.

Case A.

In this mishap the driver was lowering the 110 ft. boom plus 30 ft. fly jib of a mobile crane when the luffing A frame gantry collapsed. This resulted in damage to several jib sections.

On enquiry and reference to the load and operating chart supplied by the maker it was found that the maximum jib length which could be supported by the machine for raising from or lowering to ground level was 110 ft. on its own and 100 ft. plus 30 ft. fly jib. In this instance the assistance of another crane was required. The driver should have been aware of this.

Case B.

This refers to a tower crane which is of the telescoping self erecting type. At the time of the mishap the tower was being extended. Due to the ignorance of the parties carrying out this work an attempt was made to raise the extended section without releasing the anchorage at the base. The top section of the tower collapsed and was severely distorted necessitating the rebuilding of this section.

Case C.

The luffing A frame gantry of a mobile truck crane was damaged in this accident. It was caused by the driver using the crane with the gantry in the stowed position instead of erected. In the position where the crane was operating it was adjacent to a guy wire attached to a high tension power line pole. The driver felt that there was some likelihood of the crane fouling the guy as he slewed so in order to reduce the height above the cab of the machine he was working with the luffing A frame in the down position. He managed to lift the 6 ton load on the 40 ft. jib, slew and was about to lower the load into position when the A Frame buckled and allowed the load to lower gently into place. It was most fortunate that no one was injured.

The driver was aware of the possible hazard presented by the guy wire and took precautions to avoid it. In so doing he created another hazard by his lack of awareness that in using the crane with the A frame lowered the tension load on the luff rope was greatly increased. This resulted in the failure of that frame.

Case D.

This deals with a mobile crane with a jib approximately 80 ft. long which was being used in conjunction with another mobile crane to remove a vertical bucket elevator installation from its position. The second and larger crane was to take the main lift while the crane under discussion was to steady the load being attached to the top end. When the main lift was taken the load buckled at the slinging point which was approximately at mid height. This threw an unanticipated load on the steadying crane, which overturned. Fortunately the driver was not injured but the crane jib was extensively damaged and the truck chains were twisted.

Investigation revealed the following:—

1. The crane was not registered.
2. It had been supposedly designed for a 50 ft. jib. At the time of the mishap it had 30 ft. added together with a fly jib.
3. The accident was not reported.

These points illustrate the ignorance of design and the danger involved in making modifications without realising the hazards induced and the complete disregard of statutory obligations. These shortcomings are fostered by lack of staff to pick up these cranes and operators prior to mishaps occurring.

Each year for some time now has seen the numbers of mobile cranes increasing. With these cranes have also come increases in size, height, range of working and also complexity. In many instances crane manufacturers are designing to get the utmost in loads out of the cranes with a minimum factor of safety in many instances. In order to avoid mishaps, comprehensive data on lifting capacity under all conditions must be supplied with the machine. The owners and drivers must be fully aware of the limitations and must adhere to the maker's stipulations after they have been approved by this Branch. Shortage of staff has prevented mobile crane inspections by this Branch, from being as frequent or as thorough as desirable. Inspections and checking which has been done has been of a high standard but too many are not registered, or if registered not seen often enough.

Section 4.

PROSECUTIONS FOR BREACHES OF THE ACT.

There are no prosecutions to report.

Section 5.

ACCIDENTS TO PERSONS.

Returns 7 and 7a record accidents to persons in which machinery subject to the Act was involved, the former relating to those of a serious nature and the latter to incidents classified as being of a minor nature.

Return 7b shows accidents caused by machinery not subject to registration by this Department but investigated under the provisions of Section 50 of the Act. This is a nil return for 1964.

The overall total of occurrences shown in the three returns numbers 89.

During the year one fatality involving a lift was investigated.

Case A.

The fatal accident mentioned above occurred during repairs to the top half of one of the vertical biparting enclosure doors of a lift situated in a power house. In order to repair the section of door it had been removed from its place. The bottom section was locked in the closed position with a wooden tom under it to prevent it from dropping down when the lift was put into service again while the top half door was out. Across the gap left by the removal of the door, a rope was tied with a notice "use other side" fixed to it. The lift was then returned to service.

There was no eye witness of the accident but it appears that the deceased, for some unknown reason had his head over the lower half door looking into the lift shaft, when the car descended and the toe protection plate caught his head, inflicting fatal injuries.

The victim was an electrical fitter and as such should have been aware of the danger of inserting any part of his body into the lift shaft. He would not have been able to hear the approach of the car because of the noise made by surrounding machinery, but movement of trailing cables and other parts in the well should have indicated to him that the lift was in motion.

The notice being on the rope across the opening was not specific but did indicate that unusual circumstances existed. The rope was only a token barrier, but as the lift was located in a powerhouse and not available to the public, was considered a reasonable precaution. I am afraid the accident proves otherwise, and following the mishap the opening was completely covered with a sheet of iron.

This accident points to the necessity, when erecting barriers or warning notices, of considering all possibilities and making allowances for the unpredictable behaviour of the human race. Every precaution should be taken to eliminate hazards, whether likely or unlikely.

Other accidents to persons were unfortunately due in the main to causes which appear year after year and are well known to everybody who has anything to do with safety, guarding or operation of machines.

I think the causes can be summed up as follows:—

(1) Overeagerness and ignorance.
(2) Use of incorrect attachments for particular operations.
(3) Guards and fencing not provided.
(4) Guards and fencing provided but not in use.
(5) Guards and fencing incorrectly fitted.
(6) Poor operating techniques.
(7) Poor supervision and maintenance.
(8) Laziness and intractable attitudes of operators.
(9) Treacherous conditions underfoot due to poor housekeeping.

All or any of these conditions can be present and must be looked for and corrected by Officers of this Department, but mainly by the persons involved in the use of the machinery from the Management down to the sweeper of the floors.

As much attention as required has not been given to the inspection of machinery, once again, because staff numbers have not kept pace with expansion of industry.

Return No. 7.

Showing Number of Serious Accidents, Both Fatal and Non-fatal which Occurred in Proclaimed Districts during the Year Ended, 31st December, 1964.

"F" Denotes Fatal.

Industry	Circular Saw	Spindle Moulder (Shaper)	Buzzer (Planer)	Bark Stripper	Routing M/c (Wood)	Four Sider	Belt and Shafting	Gearing	Conveyor (Screw Belt)	Bucket Elevator	Mobile Crane	Overhead Elec. Travel. Crane	Lift	Abrasive Wheels	Shears	Lathe (Wood. Metal)	Planing M/c (Metal)	Press (Metal)	Press (Other)	Guillotine (Paper)	Rolls	Teasing M/c	Wool Processing M/c	Mincer	Bagging M/c	Cement Mixer	Can Sealer	Case Stacker	Bottle Filling M/c	Air Compressor	Totals per Industry
Woodworking and Furniture	2	2	2	1	1	1	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	9
Metal Working and Engineering	1	....	1	....	....	....	1	....	....	....	....	1	....	1	2	2	1	6	....	....	....	....	....	....	....	1	....	....	....	....	17
Printing and Allied Industries	1	....	....	....	....	....	2	....	....	....	....	....	....	....	....	....	....	....	....	1	1	....	....	....	....	....	....	....	....	....	5
Food and Drink Processing	....	....	....	....	....	....	1	1	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	4	1	....	1	....	1	....	9
Building Materials and Building	....	....	....	....	....	....	....	....	1	....	....	....	....	....	....	....	....	....	1	....	....	1	....	....	....	....	....	....	....	....	3
Mining	....	....	1	....	....	....	....	....	1	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	1	3
Wool Processing	....	....	....	....	....	....	1	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	1	....	....	....	....	....	....	....	2
Chemical Industry	....	....	....	....	....	....	....	....	1	1	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	2
Other	....	....	....	....	....	....	....	1	2	....	1	....	1F	....	....	....	....	....	....	....	....	....	....	....	....	....	....	1	....	....	6 (1F)
Totals per Type of Machine	4	2	4	1	1	1	5	2	5	1	1	1	1F	1	2	2	1	6	1	1	1	1	1	4	1	1	1	1	1	1	56 (1F)

Return No. 7a.

Showing Number of Accidents not Classed as Serious under the Act which were Reported and Investigated During the Year Ended 31st December, 1964.

Industry	Circular Saw	Thicknesser	Buzzer (Planer)	Belt Sander	Belts and Shafting	Chain Drive	Belt Conveyor	Lift	Abrasive Wheels	Drilling Machine	Wiredrawing Machine	Press (Metal)	Printing Machine	Slitting Machine (Cardboard)	Rolls	Wool Processing M/c	Brickmaking M/c	Pipe Lining M/c	Boiler Ancillary Equipment	Confectionery M/c	Biscuit Making M/c	Fan	Air Compressors	Totals per Industry
Woodworking and Furniture	1	1	1	....	1	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	4
Metalworking and Engineering	....	....	1	1	....	....	1	....	2	1	3	1	....	....	....	....	....	1	....	....	....	....	1	12
Printing and Allied Industries	....	....	....	....	....	....	....	....	....	....	....	....	3	1	....	....	....	....	....	....	....	....	....	4
Food and Drink Processing	....	....	....	....	....	2	....	....	....	....	....	....	....	....	....	....	....	....	1	1	1	....	....	5
Building Materials and Building	....	....	....	1	....	....	....	....	....	....	....	....	....	....	....	....	1	....	....	....	....	....	....	2
Wool Processing	....	....	....	....	....	....	....	....	....	....	....	....	....	....	1	2	....	....	....	....	....	1	....	4
Other	....	....	....	....	....	....	....	1	....	....	....	....	....	....	1	....	....	....	....	....	....	....	....	2
Totals per type of machine	1	1	2	2	1	2	1	1	2	1	3	1	3	1	2	2	1	1	1	1	1	1	1	33

Section 6.

EXAMINATION OF ENGINE DRIVERS, CRANE DRIVERS AND BOILER ATTENDANTS.

The Board of Examiners granted 102 Engine Drivers', 278 Crane Drivers' and 90 Boiler Attendants' Certificates dring the year.

Compared with the previous year these figures show an increase of 18, increase of 28, and a decrease of 1 respectively in the number of certificates granted.

Section 7.

STAFF and GENERAL.

The vacancy in the Inspectorial Staff, caused by the transfer of Mr. Cameron in late 1963, was filled by the appointment of Mr. Lawrie in April, 1964. In addition Mr. Smith was seconded to the Public Service Commissioner's Office, and Mr. Doohan was attached to the Branch during Mr. Smith's abscence.

This brought staff up to allowable strength but as previously pointed out nowhere near requirements to cope with present industrial expansion and proposed increases due to iron ore mining, standard gauge rail works and general factory and processing plant installations.

Design drawings for checking and approval again maintained the level of last year.

An additional 200 cranes of various types was registered. Pressure vessels showed an increase in registrations of approximately 5% and machinery 4½%. With the expansion of activities in the North of the State greatly increased distances are requiring much longer travelling time to keep up with equipment installations.

Lift installations for this year have shown an increase of 8%.

The continued increases in most of the fields of operation of this Branch continue to increase the deficiency between what can be accomplished and what should be accomplished by this Branch under its statutory obligation. This is most unsatisfactory and as I have pointed out previously leads to overloading of all members of the staff, hurried inspections and decisions due to pressure of other work, and could lead to the Branch being placed in an untenable position.

Clerical staff numbers have remained static with one resignation of a female assistant who was replaced immediately. The general increases of work in the Inspectorial and Board of Examiners sections naturally is reflected in increased demands of this section of the staff.

All staff members have been under heavy pressure during the year but have responded willingly and to the best of their ability. For this cooperation and service I wish to convey my appreciation.

I would also like to thank the Police Department for continued co-operation in reporting of accidents and assistance given in investigations where we were associated.

In conclusion on behalf of all members of this Branch our thanks for assistance give by yourself and officers of all branches of the Mines Department when requested.

E. J. McMANIS,
Deputy Chief Inspector of Machinery.

RETURN No. 8.

Showing Total of Engine Drivers' and Boiler Attendants' Certificates (all classes) Granted in 1964 Compared with 1963.

	——		Numbers 1964	Granted 1963
Winding	Competency including Certificates issued under	Reg. 40 and Section 60 of the Act	12	10
First Class	,, ,, ,, ,, ,,	Reg. 40 and 45 and Sections 60 and 63 of the Act	21	20
Second Class	,, ,, ,, ,, ,,	Reg. 40 and Section 60 of the Act	15	8
Third Class	,, ,, ,, ,, ,,	Reg. 40 and 45 and Sections 60 and 63 of the Act	14	11
Locomotive and Traction	,, ,, ,, ,, ,,	Reg. 40 and Section 60 of the Act	1	1
Traction	,, ,, ,, ,, ,,	Reg. 40 and Section 60 of the Act	....	2
Internal Combustion	,, ,, ,, ,, ,,	Reg. 40 and Section 60 of the Act	32	36
Crane and Hoist	,, ,, ,, ,, ,,	Reg. 40 and Section 60 of the Act	278	250
Boiler Attendant	,, ,, ,, ,, ,,	Reg. 50 and Section 60 of the Act	90	91
Copies	....	....	13	6
Diesel Loco.—				
Class A	,, ,, ,, ,, ,,	Reg. 40 and Sections 53 and 56 of the Act	1	....
Class B	,, ,, ,, ,, ,,	Reg. 40 and Sections 53 and 56 of the Act	7	6
			484	441

RETURN No. 9.

Revenue and Expenditure for Year Ended 31st December, 1964, and Comparison with Preceding Year.

——	Revenue 1964	Revenue 1963
	£ s. d.	£ s. d.
Fees from Boiler Inspections	6,016 5 2	5,900 16 9
Fees from Machinery Inspections	9,822 10 5	10,464 0 5
Fees from Engine Drivers	939 1 3	860 5 0
Incidentals	273 19 10	234 2 10
Total	£17,051 16 8	£17,459 5 0

Decrease in Revenue compared with 1963—£407 8s. 4d.

——	Expenditure 1964	Expenditure 1963
	£ s. d.	£ s. d.
Salaries	42,487 12 6	40,569 17 3
Incidentals	9,052 17 2	9,552 0 8
Engine Drivers' Examinations	127 0 9	145 1 7
Totals	£51,667 10 5	£50,266 19 6

Increase in Expenditure compared with 1963—£1,400 10s. 11d.

RETURN No. 10.

Showing Distances Travelled, Number Inspections Made and Average Miles Travelled for Inspections for the Year Ended 31st December, 1964.

——	Road Miles	Air Miles	Rail Miles	Water Miles	Collective Mileage all Transport Services	Number of Inspections	Average Miles per Inspection
Districts operated from Perth	105,357	1,360	*Nil*	*Nil*	106,717	33,463	3·19
Comparison with 1963	Dec. 4,973	Dec. 360	*Nil*	*Nil*	Dec. 4,613	Dec. 2,679	Inc. 0·11
Districts operated from Boulder	16,754	....	....	....	16,754	4,719	5·18
Comparison with 1963	Inc. 2,123	....	....	....	Inc. 2,123	Inc. 908	Inc. 1·34
Totals	122,111	1,360	*Nil*	*Nil*	123,471	38,182	....
Comparison with 1963	Dec. 32,850	Inc. 360	*Nil*	*Nil*	Dec. 2,490	Dec. 1,771	3·23

Note Abreviations :—Inc. = Increase ; Dec. = Decrease.

Average Miles per inspection all districts, 1964 .... 3·23
Average Miles per inspection all districts, 1963 .... 3·15
Increase per inspection compared with 1963 .... Inc. 0·08

RETURN No. 11.

Engine Drivers' and Boiler Attendants' Board Matters. 1964.

Examinations in—
Perth, 4.
Kalgoorlie, 3. Mt. Magnet, 1. Geraldton, 1.
Bunbury, 1. South-West, 3. North-West Ports, 1.
Marvel Loch, 1. Norseman, 1. Bartons Mill, 1.
Collie, 1.
Special Examinations, 92.

Examinations were held at all advertised centres.
1 Board of Inquiry
76 days on actual examinations by travelling Board.
40 days spent in Perth dealing with applications for competency certificates, examination papers and enquiries, etc.
70 days spent in travelling and looking into matters connected with engine drivers and boiler attendants.
530 applications received.
484 certificates granted.
Revenue £939 1s. 3d.

DIVISION VII

Government Chemical Laboratories Annual Report—1964

Under Secretary for Mines:

I have the honour to present to the Hon. Minister for Mines a summarised Annual Report on the operations of the Government Chemical Laboratories for the year ended 31st December, 1964.

Administration.

The Laboratories consist of 6 Divisions, a Physicist and Pyrometry Section, a library and a central office all under the control of the Director (Government Mineralogist, Analyst and Chemist). The main administrative change during the year was the filling of the position of Deputy Director, a position created late in 1963, by the promotion of Mr. R. C. Gorman formerly Divisional Chief of the Agriculture and Water Supply Division. The senior staff of the Laboratories at 31st December, 1964 were:—

Director—L. W. Samuel, B.Sc., Ph.D., M.A.I.A.S., M.R.S.H., M.Inst.F., F.R.A.C.I., F.R.I.C.

Deputy Director—R. C. Gorman, B.Sc., M.A.I.A.S., A.R.A.C.I.

Agriculture and Water Supply Division—vacant.

Engineering Chemistry Division—S. Uusna, Dr. Ing., M.Aust.I.M.M., A.M.I.E.(Aust), M.Inst.F., Divisional Chief.

Foods, Drugs, Toxicology and Industrial Hygiene Division—N. R. Houghton, B.Sc., A.R.A.C.I., Divisional Chief.

Fuel Technology Division—R. P. Donnelly, M.A., B.Sc., M.I.GasEng., A.M.I.Chem.Eng., M.Inst.F., Divisional Chief.

Industrial Chemistry Division—A. Reid, M.A., B.Sc., A.R.I.C., A.P.I.A., M.S.P.I., Divisional Chief.

Mineralogy, Mineral Technology and Geo-Chemistry Division—G. H. Payne, M.Sc., A.W.A.S.M., A.R.A.C.I., Divisional Chief.

Physics and Pyrometry Section—N. L. Marsh, B.Sc.

Librarian—Miss J. E. Maughan, B.A.

Office—Miss D. E. Henderson, Senior Clerk.

At 31st December, 1964, the staff numbered 84, being—

Professional	50
General	21
Clerical	8
Wages	5

During 1964 two of our laboratories which had been unusable because of building operations became operational again but we have not yet obtained the professional staff we can now accommodate.

The close association of these Laboratories with other Government Departments and with kindred associations was maintained during 1964 and various members of the staff are members of the following Committees—

Clean Air Interim Advisory Committee.

C.S.I.R.O. State Committee.

Food and Drugs Advisory Committee.

National Association of Testing Authorities State Committee.

Oils Committee of the Government Tender Board.

Paints Advisory Committee of the Government Tender Board.

Pesticides Registration Committee.

Phytochemical and Toxic Plants Committee.

Rivers and Waters Technical Advisory Committee.

Swan River Conservation Board.

Veterinary Medicines Advisory Committee.

Water Purity Advisory Committee.

In addition Mr. Donnelly has been appointed to the recently constituted National Coal Research Advisory Committee.

Most of these Committees meet regularly and are very active and occupy considerable time of the officers concerned, not only for the meetings, but also for inspections, preparation of information, and analyses of samples. The Pesticides Registration Committee dealt with 150 applications for registration of new pesticide formulations. The total number of applications received by this Committee to 31st December, 1964, is 1669. A matter of great concern to this Committee is the poisonous nature of most of the newer pesticides, particularly as many of them can be absorbed through the skin. On occasion the Committee has refused registration of a pesticide as being too hazardous to health; more frequently the Committee has placed an upper limit on the concentration of the active material in the formulation to be distributed or has restricted distribution to commercial pest exterminators. The Veterinary Medicines Advisory Committee dealt with 919 applications. Of these 798 were re-registrations, seven were alterations, nine were deferred, nine did not require registration under the Act, 83 were new registrations and three were rejected. For the Swan River Conservation Board we analysed 145 samples of river water and 29 samples of effluents being discharged into the river.

Equipment.

Few major items of equipment were added to our facilities during 1964; a Gelman sequential sampler and accessories for air pollution studies; a spiral separator for mineral purification; a commercial atomic absorption spectroscope to replace our home made one; a large camera for X-ray powder diffraction.

Accommodation.

Although it is pleasing to record that building extensions to these Laboratories are in progress it is extremely disappointing that construction is extremely slow. Stage 1, commenced in October, 1962, is still not fully operational; stage 2 still awaits internal fitting and stage 3 is on the drawing board. It is now nearly six years since my first formal request for additional accommodation and more than two years since building operations commenced but the effective addition to our working space is very small. In addition we have been working under all the disabilities inseparable from these building operations.

General.

The total number of registrations in 1964 was 3,551, practically the same as for 1963, 3,532. The number of samples received was 12,962 an increase of nearly 15 per cent. over the number received in 1963. The "samples in hand" (samples received but not reported) increased by more than 10 per cent. from 1,707 at the beginning of 1964 to 1,898 at the end of the year. This illustrates the demand on these Laboratories from other Government Departments and from the public but until our extra accommodation is available it will not be possible to give the service we can and should give.

The number of registrations and of samples does give some measure of our activities but does not completely describe our work. A major factor in this is the enormous variation in the amount of work associated with different samples; a good illustration of this is to compare the Agriculture and Water Supply Division where a staff of 18 handled 6,898 samples and the Engineering Chemistry Division where a staff of nine plus four wages staff dealt with 12 samples. Also it is not possible to give a statistical account of the time and effort devoted to the various Committees mentioned; to advisory work for Government Departments, to industrial firms and to the general public; attendance at Courts; visits to factories and so on.

As in previous years we have been associated with a large number of Government Departments and Table 1 shows the State Government Departments from which our individual Divisions received samples in 1964. Samples were received from 20 of the 28 Government Departments shown in the Public Service List 1964, a marked increase over the 15-16 Government Departments in past years.

TABLE 1.

Department	Division						Laboratories
	Agriculture and Water Supply	Engineering Chemistry	Food and Drug	Fuel Technology	Industrial Chemistry	Mineral	
Agriculture	+		+	+	+	+	+
Audit	....	....	....	....	....	....	....
Chief Secretary's	....	....	....	....	....	....	....
Child Welfare	+	....	....	....	....	....	+
Crown Law	....	....	+	....	....	....	+
Education	....	....	....	....	....	+	+
Electoral	....	....	....	....	....	....	....
Fisheries and Fauna	+	....	....	....	....	....	+
Forests	....	....	+	....	+	....	+
Industrial Development	+	+	....	+	+	+	+
Labour	....	....	+	+	....	+	+
Lands and Surveys	+	....	....	....	....	....	+
Local Government	....	....	....	+	....	+	+
Medical	....	....	+	....	....	....	+
Mental Health Services	....	....	....	....	....	....	....
Metropolitan Water Supply, Sewerage and Drainage Board	+	....	+	+	+	+	+
Mines	+	+	+	+	+	+	+
Native Welfare	+	....	....	....	....	+	+
Police	....	....	+	....	....	+	+
Premiers	....	....	....	....	....	....	....
Public Health	+	....	+	+	....	+	+
Public Service Commissioner	....	....	....	....	....	....	....
Public Works and Country Water Supply, Sewerage and Drainage Department	+	....	+	....	+	+	+
State Government Insurance Office	....	....	+	....	....	....	+
State Housing Commission	....	....	....	+	....	....	+
Town Planning	....	....	....	....	....	....	....
Treasury	....	....	+	....	+	+	+
Workers' Compensation Board	....	....	....	....	....	....	....
	10	2	12	8	7	12	20

It is inevitable that the work of some Government Departments overlaps to some extent and it is a further advantage of a centralised chemical group that as a focal point we can operate as a co-ordinator. We have recently had a very good example of this in the Federal sphere, on food analysis, which came to us from the Departments of Agriculture and Public Health respectively. It is probable that in no other State in Australia could this co-ordination have occurred because of the diverse authorities undertaking chemical work in other States.

The samples received during 1964 were allocated to the various Divisions of the Laboratories according to the specialised work undertaken by each Division, Table 2.

In a number of cases sample(s) were allocated to more than one Division because for the full elucidation of the problem it was necessary to call on the experience and abilities of different specialists. Such samples are not usually registered twice but do show in the totals of samples received by the Divisions so the total shown in Table 2 is greater than the total of samples quoted earlier in this report. This co-operation between, and mutual assistance of, Divisions helps to foster the policy that we are one Government Chemical Laboratories, not six separate Divisions as separate entities. Discussion and interchange of ideas between Divisions is encouraged since the problems received by one Division may be helped by, indeed may rely on, the specialists in another Division. Just as "charity begins at home" so do co-ordination, co-operation and assistance and since this is easier in one group under one control it is further support for a centralised laboratory instead of chemical sections in various Government Departments.

Fees were charged for work undertaken for some State Government Departments, Government Instrumentalities, for Commonwealth Government Departments, Hospitals, Milk Board, private firms and the general public but the greater part of our work is done free for other Government Departments, together with an appreciable amount of free mineral identification and assay to assist prospectors.

The summarised reports of the individual Divisions which follow show the very wide range of subjects dealt with by these Laboratories. Comparing 1964 with 1963 there were some marked alterations in the numbers of various types of samples received. These were:—

Marked increase—	1963	1964
Air, industrial	27	104
Apple leaves	41	158
Clover	550	1,457
Gold ores	291	411
Manganese ores	....	44
Milk	382	604
Oat plant	13	110
Pasture	263	676
Silver ores	....	90
Soils	243	864
Specimens from patients	97	166
Titanium ores	40	105
Wheat, flour	11	64
plants	39	501

Marked decrease—	1963	1964
Animal specimens	546	64
Atmospheric pollution	164	98
Copper ore	211	116
Corrosion	178	41
Dust	146	96
Iron ore	254	68
Lupins	118	11
Mineral identification	614	463
Rape seed	144	....
Silage	207	43
Tantalite	88	39
Tobacco	581	....

There was a marked increase in the number of samples received from the Department of Agriculture, from 4151 to 5307 and from the Public Health Department, from 318 to 719.

During the year the following paper was published:—

Chromatographic separation of malathion prior to infrared spectrophotometric estimation—R. C. Double, J.A.O.A.C. 1964 Vol. 47, No. 4, pp. 693-5;

and the following papers were prepared—

A new process for upgrading ilmenitic mineral sands—R. G. Becher, R. G. Canning, B. A. Goodheart, S. Uusna—Australian Institute of Mining and Metallurgy Conference 1964.

Some chemical engineering contributions from the Government Chemical Laboratories of Western Australia — Director — Chemical Engineering Conference of the Institution of Engineers 1965.

L. W. SAMUEL,
Director.

TABLE 2.

SOURCE AND ALLOCATION OF SAMPLES RECEIVED DURING 1964.

Source	Division							Total
	Agri-culture	Engineering Chemistry	Food and Drug	Fuel Technology	Industrial Chemistry	Mineralogy	Physicist and Pyrometry Officer	
State—								
Agriculture Department	4,866	....	430	1	7	2	1	5,307
Fire Brigades Board	12	....	1	....	....	....	....	13
Government Stores	....	....	139	....	6	4	....	149
Hospitals	....	....	73	4	....	....	....	77
Industrial Development Department	1	1	....	2	6	8	....	18
Labour Department	....	....	27	1	....	4	....	32
Local Government Department	....	....	....	1	....	17	....	18
Main Roads Department	....	....	....	4	....	6	1	11
Metropolitan Water Supply	171	....	6	13	2	8	....	200
Milk Board	....	....	598	....	....	....	....	598
Mines Department	376	2	28	96	6	536	27	1,071
National Safety Council	....	....	....	....	1	....	....	1
Police Department	....	....	1,069	....	....	1	....	1,070
Public Health Department	44	....	577	37	....	61	....	719
Public Works Department	401	....	109	....	23	30	....	563
Swan River Conservation Board	1	....	174	....	....	....	....	175
University	10	....	....	....	....	....	....	10
Western Australian Government Railway	1	....	8	....	....	....	....	9
Other Government Departments	15	....	14	1	4	5	....	39
Commonwealth—								
Commonwealth Scientific and Industrial Research Organisation	....	1	....	....	....	....	....	1
Department of Air	....	....	28	....	....	....	....	28
Department of Navy	....	....	1	....	....	....	....	1
Department of Works	1	....	....	....	....	....	....	1
Public—								
Free	27	....	4	....	....	879	....	910
Pay	972	8	225	46	26	796	11	2,084
United States Navy	....	....	....	....	....	38	....	38
	6,898	12	3,511	206	81	2,395	40	13,143

AGRICULTURE AND WATER SUPPLY DIVISION.

In 1964 there was an increase of 33 per cent. in the number of samples received compared with the previous year. This increase was mainly due to very large increases in the number of clover, pastures, wheat and soil samples received, primarily from Department of Agriculture experiments on the use of copper, phosphate and nitrogenous fertilisers.

Another aspect of the Division's work that has been gradually increasing over the past few years and in 1964 assumed greater importance, is in the field of water-treatment. During the year several visits of periods up to a week at a time were made by specialists from the Division to water treatment plants at Northampton, Kulin, Lake Grace, Donnybrook, Eaton and Capel.

In August we were fortunate in having two delegates at the Third Australian Plant Nutrition Conference held at the University. A considerable amount of useful information was obtained and very valuable contacts made with workers in similar fields in C.S.I.R.O. and other States' Departments.

The first stage of the building extensions was occupied this year, although they are still not completely finished. This made a considerable difference to our ability to receive, prepare and store the one third increase in samples. It is hoped that the second stage of laboratory extensions will be completed early in 1965.

The types, sources and numbers of samples received in 1964 are listed in Table 3 and details are given under the appropriate headings below.

TABLE 3.

AGRICULTURE AND WATER SUPPLY DIVISION.

	Agriculture Department	Metropolitan Water Supply Board	Mines Department	Public Health Department	Public Works Department	Other Government Departments	Fire Brigades Board	Public Free	Public Pay	University	Total
Animal—											
Liver	21	....	....	....	....	....	....	....	....	....	21
Tissue and sera	22	....	....	....	....	....	....	....	....	....	22
Urine	12	....	....	....	....	....	....	....	....	....	12
Various	9	....	....	....	....	....	....	....	....	....	9
Cereals—											
Oat Plants	110	....	....	....	....	....	....	....	....	....	110
Wheat—											
Flour	63	....	....	....	....	....	....	....	1	....	64
Plants	501	....	....	....	....	....	....	....	....	....	501
Various	6	....	....	1	....	....	....	....	7	....	14
Fertiliser—											
Act	11	....	....	....	....	....	....	....	....	....	11
Fertiliser	39	....	....	....	....	....	....	....	8	....	47
Limes	5	....	....	....	....	....	....	....	83	....	88
Various	3	....	....	....	....	....	....	....	2	....	5
Horticulture—											
Apple leaves	158	....	....	....	....	....	....	....	....	....	158
Beetroot leaves	32	....	....	....	....	....	....	....	....	....	32
Citrus leaves	30	....	....	....	....	....	....	....	....	....	30
Currants	37	....	....	....	....	....	....	....	....	....	37
Vegetable	24	....	....	3	....	....	....	....	....	....	27
Various	5	....	....	3	....	....	....	....	....	....	8
Miscellaneous—											
Chemicals	....	....	....	....	....	....	....	....	16	....	16
Conductivity cells	....	....	13	....	....	....	....	....	....	....	13
Effluent	....	....	....	....	33	....	....	1	....	....	34
Fire extinguishers	....	....	....	....	....	....	12	....	....	....	12
Minerals	....	....	....	....	....	....	....	12	7	....	19
Oilseeds—											
Cotton	....	....	....	....	....	....	....	....	12	....	12
Linseed	348	....	....	....	....	....	....	....	....	....	348
Various	5	4	1	9	7	....	....	1	18	9	54
Pastures and Fodders—											
Barrel medic	35	....	....	....	....	....	....	....	....	....	35
Clover	1,456	....	....	....	....	....	....	....	1	....	1,457
Feeding Stuffs Act	31	....	....	....	....	....	....	....	....	....	31
Grass	84	....	....	....	....	....	....	....	....	....	84
Lucerne	141	....	....	....	....	....	....	....	....	....	141
Lupins	11	....	....	....	....	....	....	....	....	....	11
Pasture	676	....	....	....	....	....	....	....	....	....	676
Poultry foods	21	....	....	....	....	....	....	....	3	....	24
Serradella	30	....	....	....	....	....	....	....	....	....	30
Silage	41	....	....	....	....	....	....	....	2	....	43
Various	30	....	....	....	....	....	....	....	14	....	44
Soils	843	3	....	....	....	....	....	....	18	....	864
Waters	26	164	362	28	361	16	....	14	782	1	1,754
	4,866	171	376	44	401	16	12	28	974	10	6,898

Soils.

The 864 samples received represent an increase of more than 250 per cent. over the soils received in 1963.

1. A series of soils from seven profiles on the Fitzroy River in the Kimberleys were analysed in detail for fundamental information on the suitability of the soils for irrigation. Several of the samples had very high exchangeable sodium percentages and were almost impermeable. These would be most unsatisfactory for irrigation. A further six soils from Alexander Island on the Fitzroy flood plain were similarly examined. These were found to be very high in soluble sulphate, due to the presence of large amounts of gypsum, which made the determination of exchangeable cations meaningless.

2. 79 soils from Wongan Hills Research Station from a long term experiment examining the effects on soil structure of various clover-wheat rotations were analysed for organic carbon for correlation with water stable aggregates.

3. From an orchard at Bridgetown where pear trees had been watered for 10 years with water containing 200 grains per gallon (2850 ppm) of total soluble salts, soils were examined in detail to observe the effects of this saline irrigation water. The pear trees had recently become unhealthy in appearance and the size of the fruit was considerably reduced. Examination of the soils showed an accumulation of salt in the surface and to a lesser extent at depth. There was no change in the exchangeable sodium percentages of the soils, which were still quite low. As the permeability of the soils had not been reduced, the recent installation of drains should reduce the salt accumulation.

4. From a long term ley rotational experiment at Wongan Hills Research Station a series of soils was analysed for nitrogen and the results tabulated below show the increase of soil nitrogen under clover pasture. The smaller number of samples from the 3rd, 4th and 5th year under clover treatments could account for some minor variations.

Treatment— After	Wongan Hills Research Station Total soil nitrogen, N Per cent. dry basis Range	Average
Fallow	0·020–0·031	0·025
1st wheat crop	0·023–0·034	0·028
2nd wheat crop	0·020–0·030	0·025
1st year clover	0·027–0·038	0·033
2nd year clover	0·032–0·048	0·038
3rd year clover	0·036–0·042	0·038
4th year clover	0·030–0·038	0·034
5th year clover	0·042–0·043	0·042

5. From the Keep River, Weaber and Carlton Plain areas of the Ord irrigation scheme, 18 soils were examined in detail for comparison with 1944 soil survey analyses of the Carlton Reach area now used for irrigation.

6. Exchangeable cations were determined on 60 soils from Merredin and Wongan Hills Research Stations to find the effects of high rates of calcium ammonium nitrate, sulphate of ammonia and urea applied each year 1961 to 1964. The soils were all very low in cation exchange capacity having only of the order of 2 - 3 milliequivalents per 100 grams. The main effect was the slight lowering of pH and of exchangeable magnesium at Merredin by sulphate of ammonia. At Wongan Hills no significant changes were observed in any of the treatments.

7. The Department of Agriculture wished to make a large number of field measurements of some characteristic that would correlate well with specific conductivity of a saturation extract of soils from Kununurra so chloride and the specific conductivities of saturation paste, 1:1 extract, 1:1 paste and 1:5 extract were determined for 21 samples covering a range of these soils. Each of

these properties was graphed against the corresponding specific conductivity of the saturation extract. Saturation paste measurement gave the best correlation with saturation extract but even saturation paste measurements are tedious to make. Specific conductivity of 1:5 extract is the simplest to perform and gave reasonable correlation with saturation extract measurements. Over the range pC saturation extract 1.5 - 3.0 the following equation was found to apply with sufficient accuracy for interpretation of results in terms of U.S.D.A. standards—

pC saturation extract, 25°C = 0.87 (pC 1:5 extract - 0.35).

8. 20 soils from Lancelin Island area and 17 soils from Badgingarra Research Station representing soil types in these areas were analysed in detail to give fundamental information about the sandy soils that are being developed in these districts.

9. Copper in soils.

(a) Samples of coarse yellow brown sand from light land on Merredin Research Station were analysed for total and E.D.T.A. soluble copper. Though typical of soils in the district that had given response to copper fertiliser, these soils had shown no evidence of any response to added copper. Neither the total nor the E.D.T.A. soluble copper could explain the lack of response of these soils to copper fertiliser.

(b) Bramley Research Station.

(i) Soils from a rate of copper sulphate trial had very variable total copper but the E.D.T.A. soluble copper of untreated soils averaged 0.13 ppm copper and soils treated with 2.5 and 7.5 lbs. of copper sulphate per acre averaged 0.20 and 0.30 ppm of "available" copper respectively.

(ii) From a rate and source of copper trial on a different experiment, soils treated with 1 and 5 lbs. of copper sulphate per acre and equivalent amounts of commercial copper ore had varying total coppers but both treated and untreated soils showed low "available" copper levels of around 0.11 ppm.

(c) Esperance Research Station.

(i) From a copper and zinc fertiliser trial in which either no treatment, copper, zinc, or copper plus zinc was applied in 1951 and in both 1951 and 1963, 32 soils were received for E.D.T.A. soluble copper. The no copper treatment soils averaged 0.11 ppm copper, soils that had had copper applied in 1951 averaged 0.18 ppm copper and soils that had had copper applied in both 1951 and 1963 averaged 0.26 ppm copper.

(ii) From a similar trial to (c) (i) above 96 samples taken in 1963 were received from plots on which wheat, linseed and oats had shown a visual response to copper. For the no copper treatments an average of 0.12, 0.14 and 0.17 ppm "available" copper was found on the wheat, linseed and oats plots respectively. On the plots that had copper in 1951, 0.17, 0.21 and 0.26 ppm of available copper was found respectively and on plots that had copper applied in both 1951 and 1963 an average of 0.93, 1.2 and 1.6 ppm of "available" copper was found on the wheat, linseed and oats plots respectively.

(iii) From the same area as (c) (ii) above a further 24 samples were taken in 1964 prior to sowing with wheat. The high levels of E.D.T.A. soluble copper in these soils indicated that any response of wheat to copper applied in 1964 would be most unlikely.

(iv) Thirty-two samples of Fleming gravelly sand, having a grey organic matter A horizon to a depth of 2-4 inches and gravel occurring at about 18 inches, were sampled at 0-3 inches and 3-6 inches for total and E.D.T.A. soluble copper. Total copper was low and variable in all soils. The "available" copper averaged 0.12 ppm in the non copper treated surface soils and 0.36 ppm in the copper treated surface soils. The 3-6 inches samples were all low in "available" copper, averaging 0.04 ppm and showing no relationship to treatment.

Water and Water Treatment.

The examination of water and problems of water quality from all parts of the State from Esperance in the south to Wyndham in the north and Eyre Highway in the east to Denham in the west for the Public Works Department, Metropolitan Water Supply Board, Geological Survey, other Government Departments, private industry, farmers and householders has again been an important function of this Division in 1964.

Of the 1754 samples received the following were of interest:—

1. Boyanup water supply.—Water from a new bore for a town supply was found to be very corrosive with an extremely high free carbon dioxide content and also a high iron content. Aeration alone was found unsatisfactory in reducing the free carbon dioxide or in precipitating the iron in a form readily removed by an upflow clarifier or by filtration. Because of this an alternative source is being sought by the Public Works Department.

2. Boyup Brook water supply.—A problem of bad odours in the town supply was found to be due to decomposing algae in the town reservoir. The solution to the problem was one of physical removal of the dead algae and break-point chlorination of the water.

3. Muresk solar water still.—Supply water to the joint C.S.I.R.O. and Public Works Department experimental solar still was examined in relation to scale formation. It was found that the water could be concentrated 20-fold at 20° C., 12-fold at 40° C. and 3-fold at 60° C. without scale formation.

4. Northampton water supply.—Visits were made to the Gwalla shaft water treatment plant in April and August by Mr. Platell to check on the operation of the copper removal plant that had been installed on our advice. In previous years water had to be pumped to waste from this shaft during the winter to keep the water level below the oxidised ore zone to prevent high levels of copper in the water. The loss of water caused by this reduced the supply avaliable in summer, causing water restrictions in the town and considerably increasing costs. With the present treatment plant high levels of copper can easily be handled and there has been no need to pump to waste this year.

5. Eaton water supply.—An inspection of the water treatment plant was made to investigate the reason for the overloading of the filters. This indicated that sufficient iron was not being removed by the upflow clarifier. Aeration and flocculation tests were made on samples taken back to the laboratory. It was found that the bore water, which has 20 ppm of ferrous iron, 50 ppm of free carbon dioxide and pH 6.4, did not have long enough retention time to oxidise the iron prior to the upflow clarifier. With the present plant design the most satisfactory method of overcoming this was to increase the rate of oxidation of the iron by adding caustic soda part of the way down the aerator, to raise the pH.

The settling rate of the precipitated iron was increased by adding 0.5 ppm of the polyelectrolyte Superfloc 20, part of the way down the inner cone of the clarifier. This combined treatment gave 80-90 per cent. removal of iron in the clarifier so reducing the load on the rapid sand filter.

6. Kulin water treatment plant.—Kulin water supply is obtained from clay catchment area draining into a clay dam. The turbid water from the dam is treated with alum and passed through an upflow clarifier to remove the flocculated clay. The treatment plant had worked through the winter satisfactorily when the low draw allowed longer settling time for the floc. With the increased summer demand the floc was being carried over into the storage reservoir. A series of plant trials and laboratory flocculation tests were made. Plant trials proved that without the formation of a more rapid settling floc, no simple alteration to the plant could prevent the floc from being carried over. About 40 different combinations of rates and mixtures of various flocculants and flocculant aids were tried and a number of considerably better alternative treatments were found. The selected treatment had to be chosen not only on the basis of the fastest settling floc, the most economic, the one requiring a minimum number of chemicals, the one that did not excessively lower the pH in the clarifier section and the one that gave the minimum sludge volume but also most importantly the one which would give a tenacious floc, that would not readily disperse on restarting after overnight shut down. Two treatments that satisfied all these requirements were 40 ppm of alum followed by a further 40 ppm of alum added a third of the way down the inner cone and 30 ppm of alum and 40 ppm of sulphuric acid followed by 10 ppm of sodium aluminate added a third of the way down the inner cone.

7. Lake Grace water treatment plant.—A similar problem to Kulin water supply existed at Lake Grace. A two to three-fold increase in the settling rate was achieved by the addition of 80 ppm of alum followed by 5 ppm of sodium aluminate added 4 feet down the inner cone.

8. The first case of a sample of natural water in Western Australia for which the total soluble salts was not harmfully high but the magnesium content was, was observed in a water from "Bitter Bore" on Mt. Carnage Station at Ora Banda. This water had a total salt content of 8,470 ppm (593 g.p.g.), normally satisfactory for all sheep, but contained 1,000 ppm of magnesium, equivalent to 3,900 ppm of magnesium chloride. Several sheep had died from scouring after several days on this water. This is in agreement with the findings of A. W. Pierce Aust. J. Agr. Res. 1959 p. 725, who found that over 0.20 per cent. (2,000 ppm) of magnesium chloride in water was detrimental to some sheep, causing occasional diarrhoea and reduced food intake.

9. On behalf of the Metropolitan Water Supply Board an investigation was made into the performance of a magnetic water treatment unit that was currently being sold in Perth. This unit was claimed amongst other things to prevent corrosion and to prevent scale formation in hot water services and boilers. Since the end of the 19th century there have been many types of water treatment gadgets proposed that supposedly physically alter the water by some magnetic, electrostatic, electronic or pseudo scientific principle. None of these have stood the test of time and neither is the present one likely to.

Scale formation tests were made on samples of treated and untreated water and no distinction could be found between the two. Neither was any evidence found that treated water could remove already formed scale, as was claimed. Microscopic and X-ray diffraction examination of scales from treated and untreated water showed them to be identical. All our investigations confirmed our opinion of the units being of no value and confirmed the published reports by B. K. Welder and E. P. Partridge in Ind. Eng. Chem. 1954 p. 954 on "Practical Performance of Water Conditioning Gadgets" and by R. Eliassen et al in J. Amer. Wat. Works. Assoc. 1958 p. 1371 on "Experimental Performance of 'Miracle' Water Conditioners."

10. Ground water pollution.

(a) A problem of pollution of a private bore at South Perth was examined. Water from the bore had been used for garden reticulation for years until recently when vigorous frothing was observed at sprinklers and when the water was run into a bucket. Analysis of the water showed the presence of 3 ppm. of alkyl benzene sulphonates. This was derived by pollution of the ground water by the unchanged detergent in the effluent from the septic tanks of a recently built large block of flats nearby. The presence of the detergent was more of a nuisance than a hazard in this case as scheme water was available for normal domestic use. In places such as Rockingham and Safety Bay where all domestic water is drawn from shallow bores and quite large blocks of flats have recently been built, similar pollution could be a serious problem unless bio-degradable detergents become standard use.

(b) Pollution of ground water, the only source of domestic water at Kwinana, in the vicinity of a chemical manufacturing plant, by effluent disposal into the ground had caused concern to the local health authorities. Similar experience at Kenwick several years ago indicated that the phenolic effluent could travel several miles. Samples of ground water taken from bores at dwellings 500-800 yards from the disposal bore fortunately showed no signs of pollution. The levels of phenol, the indicator of pollution, were all below 0.001 ppm.

11. Copper water pipes.—High levels of copper in the scheme water at the Laboratories had been noticed after the replacement of old galvanised iron pipes with new copper pipes. This did not occur in all pipes, but high levels of 2-3 ppm. of copper in water that had been standing in the pipes overnight were common. After several months the level dropped back to a normal 0.05 ppm. The high level in some pipes and not others was attributed to these pipes being newer and not oxidised to the usual tarnished copper colour and ageing of the pipes in use built up a protective surface coating.

At levels of 2-3 ppm. copper in the water the taste was obvious to some members of the staff, though the majority could not taste copper in water of this level. Aluminium kettles were found to pit very rapidly with this water and if water was left in them for several days after use a voluminous white deposit of aluminium hydroxide was formed.

Fertilisers.

1. Fertiliser Act.—Only 13 samples of fertilisers registered under the Act were examined in 1964. Of these 1 of 9 registered for nitrogen, 1 of 3 for water soluble potash, 1 of 12 for citrate soluble phosphoric anhydride, 1 of 13 for acid and total phosphoric acid, 2 of 4 for copper and 1 of 6 for fine material (b) did not comply with the registered analysis. This is reasonably satisfactory but suggests that 2-3 times this number of samples would be warranted in 1965.

2. Because local superphosphate is now made from a mixture of Christmas Island and Nauru Island rock phosphate the necessity of examining the trace element content of current superphosphate arose. Previously when Nauru rock phosphate had been used the presence of 4-500 ppm. of zinc in the superphosphate prepared from it was often sufficient to satisfy the zinc requirements of some marginally deficient soils.

The results of analyses of 23 samples of superphosphate supplied to Department of Agriculture Research Stations late in 1963 and early in 1964 are given below.

Minor Elements in 1963–64 Superphosphate

	Range	Average
	ppm	
Boron, B	3–10	5·5
Cobalt, Co	0·8–2·0	1·1
Copper, Cu	19–360	99
Manganese, Mn	28–90	63
Molybdenum, Mo	less than 0·1–1·2	0·26
Selenium, Se	0·5–2·3	1·1
Zinc, Zn	315–550	393

3. A sample of residue from pelleted potato manure B applied to the soil in July 1963 was received in January from a market gardener who thought from the size and appearance of the residual pellets on the surface of the soil that all the original fertiliser was insoluble. Analysis of the sample showed that 95-98 per cent. of the water soluble nitrogen, phosphorus and potassium had been leached from the pellets and that the remainder consisted almost entirely of calcium sulphate from the superphosphate in the potato manure.

4. More than 80 samples of lime sands and limestones were received for examination, the majority of them from Garden Island.

5. Detailed examination of two samples of finely ground limestone which had been used for lime pelleting of legume seed and had caused almost complete lack of germination proved the cause to be due to them having a 1:5 pH of 12.5. The high pH must have been due to contamination of the samples with free lime as subsequent samples prepared identically had a normal pH of 9.6 and these were found to be satisfactory.

6. A small quantity of barium selenate for selenium fertiliser trials was prepared by roasting readily available sodium selenite at 700-800°C to convert it to selenate. This was dissolved in water and barium selenate precipitated by the addition of barium chloride.

7. An unusual limesand was received from Esperance. This was a phosphatised limestone as occurs on the islands of the Recherche Archipelago. It had 38 per cent. calcium carbonate and 10 per cent. phosphoric anhydride but also had 27 per cent. of gypsum present. The presence of the gypsum is difficult to explain as the deposit from which the sample was taken was well away from any salt lakes and was on a relatively well drained area.

Pastures, Fodders and Stock Foods.

1. Feeding Stuffs Act.—31 samples of registered stock foods were analysed this year. Of these, 14 were deficient in crude protein, two were deficient in crude fat and five had an excess of crude fibre. All samples complied with their other registered analyses. The number of samples deficient in crude protein appears excessive but in most cases the deficiency was only very slight. No margin of deviation from the registered analysis is allowed under the Feeding Stuffs Act as distinct from the Fertiliser Act, but the Department of Agriculture generally accepts a 10 per cent. deviation. On this basis only two of the samples would be unsatisfactory.

2. From a residual copper fertiliser trial at Bramley Research Station 20 samples of pasture separated into monocotyledon species and dicotyledon species were received for analysis for copper. With nil, 2½ and 7½ lbs. of copper sulphate per acre applied in the autumn of 1963 the monocotyledon species averaged 2.6, 3.8 and 5.0 ppm of copper respectively and the dicotyledon species averaged 3.4, 4.2 and 5.5 ppm of copper respectively.

3. From a cobalt fertiliser residual trial at Bramley Research Station where 1, 3, 9 and 18 oz. cobalt sulphate per acre had been applied in 1961 in one trial and 1, 3 and 9 oz. of cobalt sulphate had been applied in another trial, there was no increase in cobalt uptake over the nil treatment, showing the negligible residual value of cobalt fertiliser on this soil.

4. From a property at Waterloo, where a scouring syndrome had occurred a few weeks after pastures had been top dressed with molybdenum, high levels of 11 ppm molybdenum were found in the pasture associated with only 6 ppm copper. These would be in the right proportion to be responsible for the scouring.

5. From a rate of urea trial at Merredin, 78 samples of mixed grass pasture cut on 23rd July and 3 weeks later on 13th August were examined for yield and total and protein nitrogen. The averages of three replicates for each sampling show that for very early growth no increase in yield was obtained with application of more than 100 lbs. per acre of urea. For later winter growth yields increased with added urea of up to 500 lbs. per acre of urea. At both sampling times total and protein nitrogen were generally found to increase with the rate of application of urea.

6. Silage.—Only 32 samples were received this year from the Silage Competition. As distinct from previous years when all entries were submitted, this year only those samples likely to be amongst the winners were forwarded for analysis.

7. Selenium in Pasture.—A further 76 pastures and 20 clover samples were received from a continuing survey of selenium in pasture. Of these samples, 52 pastures and 15 clovers (from Bullsbrook, Darkan, Esperance, Gibson, Harvey, Kendenup, Kojonup, Millbrook, Narrikup, Northam, Northcliffe, Quairading, Rocky Gully, Tenterden, Vasse, Wannerup, Windy Harbour, Winijup, Woogenellup and Yallingup) had levels of less than 0.01 to 0.04 ppm selenium and 24 pastures and 5 clovers (from Ambergate, Busselton, Coolup, Darkan, Gingin, Harvey, Pinjarra, Quairading, Roelands, Tenterden and Waroona) had 0.05 to 0.34 ppm selenium. Within the less than 0.01 to 0.04 ppm areas there were many examples of outbreaks of white muscle disease or chronic ill-thrift.

8. Cobalt in Pasture.—Almost concurrently with the selenium in pasture survey, a continuing survey of cobalt in pasture was conducted. 58 pasture and 20 clover samples were received from the same districts as in 7. above. As many of the properties from which the samples came had had cobalt fertiliser applied no separation of the results into districts was possible, but many examples of chronic ill-thrift in cattle and sheep on pasture containing less than 0.07 ppm cobalt, were observed by the Animal Health Laboratory veterinary officers.

9. Because of dramatic responses to selenium by pigs suffering from ill-thrift a number of supplementary stock foods were examined to see if they would provide sufficient selenium to the diet. The foods examined were meatmeal, dried butter milk and skim milk, whalemeal and spray dried whale solubles. These were found to contain 0.09-0.30, 0.02, 1.6-6.1 and 3.2 ppm of selenium respectively.

10. 9 samples of meatmeal and whalemeal were examined in connection with a severe outbreak of hepatitis in metropolitan poultry flocks. It was thought that high cholesterol levels in the feed supplement might be associated with the outbreak. Levels of 0.02-0.29 and 0.002-0.005 per cent. were found in the meatmeal and whalemeal samples respectively.

11. Numerous miscellaneous pastures including sorghum, hay, arthrocnemum, galenia, pennisetum, panicum, barrel medics, serradella, Flinders grass, kapok bush, ipomoea, sporobolus, trianthema, plagianthus and over thirty miscellaneous stock foods were examined for estimation of their food value.

Cereals.

1. Oats.

(a) 35 oaten straw samples from an old series of rates of superphosphate trials were analysed for phosphorus. The treatments applied per acre were 28, 56, 112 and 168 lbs. of superphosphate and 28, 86, 112 lbs. of superphosphate with 99, 66 and 33 lbs. of gypsum, applied in 1951 to 1954 and again in 1958. In 1960 a high residual value of previous dressings was observed and these samples taken then for yield figures were now required for phosphorus uptake results. Average results showed increasing phosphorus uptake with previously added superphosphate and appreciable uptake at all levels.

(b) Samples of oat grain from a property at West Wagin where an outbreak of white muscle disease had occurred in hoggets fed home grown oat grain several days prior to the first losses, were found to have only 0.01 ppm of selenium.

2. Wheat.

(a) The 1963-64 f.a.q. wheat and flour milled from it on a Buhler laboratory mill were analysed as below:

	F.A.Q., 1963–64	
	Wheat	Flour
	Per cent.	
Moisture	9·7	14·3
Ash at 13·5% moisture	1·29	0·43
Protein (N x 5·7) at 13·5% moisture	8·5	7·0
Maltose (Kent Jones)	....	2·81

(b) 60 flour samples were received for moisture, ash and protein determination. These were check samples taken from export shipments going to Russia, to see that they met the requirements of the export contract. Early samples showed ash figures higher than the contract figure of 0.5 per cent. but when this was pointed out to the flour mills concerned, subsequent samples all complied with the contract conditions.

(c) From an experiment at Bodallin using applications of 2 rates of superphosphate, 3 rates of urea and 2 rates of molybdenum oxide, 22 samples of Bencubbin wheat tops were analysed for ammonia, nitrate, protein and total nitrogen, molybdenum and dry weights. The yield was found to increase with added molybdenum with all rates of urea except at the highest rate of superphosphate application. Ammonia nitrogen showed no trend with the treatments; nitrate nitrogen generally increased with urea application. Total and protein nitrogen uptake increased with urea application in the absence of added molybdenum, but were unaffected by urea in the presence of molybdenum. Molybdenum uptake was found to increase with molybdenum application but was unaffected by other treatments.

(d) From a rate and time of application of urea and sulphate of ammonia at Wongan Hills Research Station, 54 samples of wheat tops were analysed for total nitrogen and dry weight. Nitrogen uptake was found to decrease with added urea or sulphate of ammonia at all rates and times of applications. This was because of the considerably increased yield. The increase in yield was 6 fold over the nil treatment for the highest rate of sulphate of ammonia application. Sulphate of ammonia generally gave greater increases in yield than equivalent amounts of urea, at all rates and times of application. Whether applied before, at, or several weeks after planting did not greatly affect the yield from either fertiliser, except for the highest rates when it was better to apply the fertiliser several weeks after planting.

(e) From a rate and method of application of sulphate of ammonia trial at Wongan Hills Research Station 36 wheat plant tops were analysed for total and protein nitrogen and dry weight. With sulphate of ammonia drilled with the seed the yield increased to a maximum of 1⅜ times the nil treatment with 112 lbs. per acre. With rates greater than 336 lbs. per acre the yield decreased below the nil treatment. With sulphate of ammonia broadcast, yields increased to a maximum of 2½ times the nil treatment with 224 lbs. per acre but above this level the yields decreased slightly from the maximum. Protein and total nitrogen were found to increase with increasing rates of sulphate of ammonia, whether drilled with the seed or broadcast.

(f) 48 samples of wheat roots and tops from a rate of copper sulphate experiment on gravelly ironstone soil at Wandering showed such variations in replicate determination of copper that either treatments had been mixed or there had been contamination of some samples.

(g) From rates of copper sulphate application trials at Esperance Downs and Badgingarra Research Stations 90 samples of roots and tops were analysed for copper. These generally showed increasing copper uptake with applied copper but again as in the trial at Wandering, (f) above, there were several erratic results especially in the roots, though these may have been due to excessive soil contamination.

(h) 64 samples of roots and tops sampled at the 6-8 leaf stage were analysed from a copper residual trial at Esperance Downs Research Station. The average of results of replicate copper determinations showed the residual effect of copper applied in 1951 in the tops but no evidence of a residual effect in copper uptake in the roots was observed.

Plant Nutrition.

1. Apples.

(a) 96 samples of apple leaves from Stoneville Research Station representing 6 replicates of 14 root stocks of Granny Smith variety and 2-4 replicates of 9 root stocks of Jonathon variety were received for analysis. All samples were showing nutritional deficiencies. The range of the various nutrients found for each variety is given below.

	Apple Leaves	
	Granny Smith	Jonathon
	Per cent. dry basis	
Calcium, Ca	0·66–0·85	0·64–0·90
Phosphorus, P	0·12–0·15	0·13–0·16
Potassium, K	2·06–2·56	2·08–2·61
Nitrogen, N	2·08–2·22	2·08–2·40
	p.p.m. dry basis	
Copper, Cu	8·5–17	6·0–23
Manganese, Mn	67–94	52–101
Zinc, Zn	14–21	15–27

(b) From fertiliser trials on orchards at Argyle and Donnybrook 23 samples of leaves were received for nitrogen, phosphorus and potassium analysis. The results showed no general increase in uptake of nutrients with the respective fertilisers.

(c) More than 50 samples of leaves were received from Bridgetown, Manjimup, Karagullen, Donnybrook, Kendenup, Mt. Barker and Denmark for analysis in connection with calcium nitrate bitter pit trials, potash trials, urea trials and miscellaneous nutritional problems.

2. Beetroot leaves.—From an experiment at Spearwood where infection with sugar beet eelworm and root-knot eelworm was suspected of complicating a manganese deficiency, 32 samples were received for analysis. The degree of infection was not found to affect the response to manganese treatment and a single soil dressing of manganese was found to be as beneficial as several manganese sprays in increasing manganese uptake. From this area bulked samples of affected leaves were found to average 11 ppm. of manganese and bulked samples of healthy leaves averaged 89 ppm. of manganese.

3. Cauliflower leaves.

(a) Further investigation of "tip burn" in cauliflowers on young inner leaves of plants at Medina Vegetable Research Station confirmed literature evidence that "tip burn" tissue was much lower in calcium than nearby healthy tissue. The opposite was found to apply to potassium.

(b) Other "tip burn" samples investigated from an area at Medina showed hollowing and rotting of the curds indicative of boron deficiency but this was not confirmed by analysis.

4. Celery.—An additional six samples of affected and healthy leaves from Balcatta and Osborne Park when analysed for boron did not confirm a response to borax spray found in 1963 as being due to boron.

5. Citrus Leaves.—A number of samples from Stoneville, Edjudina and Capel were analysed for confirmation of visual deficiency symptoms and for assessment of the nutrient status of the trees.

6. Clover.—The 1,456 samples of clover received in 1964 was an increase of 165 per cent. on 1963. These samples included:—

(a) Copper experiments.

(i) 20 samples from Bramley Research Station taken in connection with soil copper availability consisted of native clovers and subterranean clover. Both species were found to increase in copper uptake approximately to the same extent with added fertiliser copper.

(ii) From pot experiments which had been treated in 1960 with different copper minerals and copper ores available in this State 200 samples were received for copper determination. The availability of the three primary zone minerals malachite, chalcocite and chalcopyrite was shown to be in that descending order, which corresponds to the order of oxidation. Fine grinding (to minus 100 mesh) of the malachite, and roasting and fine grinding of the sulphide ores to convert them either to sulphates or further to oxides were necessary to make these ores into satisfactory sources of copper.

(iii) 18 samples from a copper survey at Ardath, Gabbin and Wongan Hills showed that the clover in these areas was naturally high in copper and that the addition of 10 lbs. of bluestone per acre or the equivalent in copper ore increased the copper uptake.

(iv) Further samples from the copper survey from the Moora district showed considerable seasonal variation in copper levels. Levels with added copper were slightly higher than without, but winter growth contained nearly twice the amount of copper as during the spring flush growth period and the copper content in summer had risen again to about the same as in the winter.

(b) Sulphur Experiments.—A series of six experiments was initiated by the Department of Agriculture in the winter of 1963 to determine the response of sub-clover pasture in the Avon Valley, primarily to sulphur but also to phosphorus. From only one site was there evidence of response to sulphur and this was on an area that had received little superphosphate since 1940. 59 samples were analysed for inorganic and total sulphur, phosphorus and total and non protein nitrogen. M. B. Jones, Calif. Agric. 1962, 16:4 suggests that the critical level between deficiency and sufficiency of inorganic sulphur for maximum sub-clover growth is 0.017 per cent. The results on this site showed that even the controls had this amount or more of inorganic sulphur. The addition of only 45 lbs. per acre of superphosphate raised the inorganic sulphate to well above this level. The addition of sulphur and phosphatic fertiliser increased the levels of total and non protein nitrogen and total and inorganic sulphur over those with phosphate fertiliser only. The results confirm the belief of the Department of Agriculture officers that wherever in Western Australia phosphate fertiliser has to be applied and this is supplied as superphosphate, the superphosphate will supply sufficient sulphur for maximum plant growth.

(c) Phosphate experiments:

(i) From a rate and time of superphosphate top dressing trial 60 samples of sub-clover pasture were received. Superphosphate was applied to different plots at the rate of 90 lbs. per acre at six weekly intervals starting on 1st December through till 1st June. At the normal autumn top dressing period 45, 135 and 180 lbs. per acre were also applied. Phosphorus uptake was slightly lower for the December top dressing than in other months. The yield increased to a maximum with April top dressing and decreased from this with June top dressing. Yields with 135 and 180 lbs. per acre in April were only slightly higher than with 90 lbs. per acre.

(ii) From a glass house trial on virgin Boddington gravelly sand 187 samples were received for the influence on phosphorus uptake of (a) the time, rate and granular size of top dressed superphosphate and (b) the time, rate, frequency and intensity of applied water as a measure of the effect of summer or early season rain. As the highest treatment of superphosphate of 600 lbs. per acre only raised the phosphorus uptake to 0.10 per cent compared with 0.08 per cent in the nil treatment no significant effect could be interpreted from the results.

(iii) A similar glass house trial tested the effect of time and rate of superphosphate top dressing on gravelly sand and on sand. The results of analysis of 101 samples showed that phosphorus uptake increased about the same at each time of top dressing on the sandy soil up to the maximum top dressing rate. On the gravelly soil no increase in phosphorus uptake was achieved above that obtained with the minimum top dressing rate, for both times of top dressing. Heavy watering in February had no effect on phosphorus uptake on the gravelly soil.

(iv) 240 samples were received from another glass house trial investigating the effect on sub-clover of top dressing before the break of the season (in February) or after the break of the season (in April), the rate and granule size of superphosphate and the level of previously applied superphosphate. On Boddington gravelly sand phosphorus uptake increased with added superphosphate on the virgin soil, being generally higher with April top dressing and the fine granule size. When this soil had had 800 or 1,800 lb. per acre previously added, additional superphosphate had little effect on phosphorus uptake. On siliceous gravelly sand at Esperance with nil, 750 or 1,750 lb. per acre of superphosphate previously applied, the phosphate uptake increased with additional added phosphate, the increases being generally greater with April top dressing and with the finer granule size.

(v) At Bridgetown on a rate of superphosphate and lime trial a high response to superphosphate was obtained but a decrease with high rates of lime was found, suspected to be due to induced manganese deficiency. Analysis of samples showed that phosphorus uptake increased with added phosphorus and manganese was found to decrease with added lime for nil and 180 lb. of superphosphate per acre treatment, but only decreased at the highest rate of lime treatment with 60 lb. of superphosphate per acre.

(d) Over 250 samples of clover were received from strain trails investigating the feeding value of dried off pasture in the South-West. At Hopetoun, Bacchus Marsh, then Geraldton and Mt. Barker strains were the best of nine tested. At Muradup, Bacchus Marsh was outstandingly the best. At Harvey, Boddington and Williams, strain differences were not so great except that in all cases Dwalganup was the lowest protein yielder.

At the Harvey trial the addition of molybdenum was beneficial in increasing the protein content of all strains.

(e) The balance of clover samples were mainly concerned with diagnostic problems either for plant growth or animal nutrition.

7. Lucerne.

(a) From three rhizobium strain trials on properties east of Mt. Barker 101 samples were received for total nitrogen, to measure the effectiveness of various strains to fix nitrogen for legume growth. These showed increases of nitrogen uptake from 2.07 to 2.58, 1.67 to 2.62 and 2.41 to 2.58 per cent. respectively for each of the trials, between uninoculated plants and the best response by inoculated plants.

(b) From Esperance Downs Research Station 10 samples were received for nitrogen, cobalt, copper and zinc analyses, from a trace element trial involving the addition of copper, zinc and molybdenum in all possible combinations. Nitrogen, cobalt and copper uptakes were not affected by the treatments but zinc increased from near deficient levels to satisfactory levels with added zinc. From another site where zinc appeared to be detrimental to the establishment of lucerne and there was evidence of a slight response to cobalt, analysis of six samples showed no response in uptake of copper or nitrogen by the addition of lime, copper, zinc, molybdenum or cobalt. Zinc uptake was found to treble with added zinc, and cobalt uptake increased from 0.08 ppm in the absence of cobalt to 0.87 ppm when cobalt was added.

(c) On Forest Grove gravelly sand at Bramley Research Station considerable inincreases in yield were obtained in a lucerne establishment trial with inoculation, inoculation and pelleting and even greater increases when lime up to two tons per acre was added. This soil which had had a total of two tons of superphosphate per acre applied in the past had a surface pH 6.2. The surprising increases in yield due to lime with such a relatively high pH were considered to be due to possible increased phosphate availability or to a reduction in heavy metal toxicity. Twenty-four samples were received from this experiment involving treatments of nil and added molybdenum, no inoculation, inoculation with and without lime pelleting and nil, 2 cwt. drilled, 2 ton broadcast, and 38 cwt. broadcast and 2 cwt. drilled of lime. Added molybdenum, lime, inoculation or inoculation and pelleting were found to have no effect on phoshorus, aluminium, manganese or zinc uptake. Added molybdenum or lime had no effect on nitrogen uptake but inoculation increased nitrogen uptake slightly. Hence these results do not give any indication as to the possible reason for such large yield responses with added lime.

8. Lupins.—Only eleven samples were received this year compared with 118 in 1963. These samples were from summer lupinosis trials at Dandaragan and Mingenew.

9. Onion.—Samples of onion leaves from Spearwood and Medina which had responded to bluestone application, showed increased copper uptake and a sample grown on an area previously sown to beetroot which had shown acute manganese deficiency symptoms was found on analysis to be very deficient in manganese.

10. Tick beans.—From an experiment at Herne Hill on the use of lime to control heavy metal toxicities in tick bean cover crops in a vineyard, 8 samples were analysed for nitrogen, phosphorus, potassium, calcium, aluminium, boron, cobalt, copper, manganese, molybdenum, nickel and zinc. The main difference between the unlimed chlorotic leaves of plants showing no nodulation and with rotted roots and the limed (2 tons per acre) green, healthy plants with prolific nodulation and good healthy roots was the increased nitrogen and potassium in the healthy plants from 1.49 to 3.36 and 1.50 to 2.78 per cent. respectively and the decreased aluminium, copper, manganese, nickel and zinc from 840 to 200, 21 to 7, 570 to 29, 4.8 to 0.8 and 230 to 51 ppm respectively.

11. Tobacco.—No samples of tobacco were received in 1964 but 575 samples of tobacco received in 1963 and not completed then, were finished this year. These samples are probably the last from tobacco experiments in this State for a long time.

(a) 431 samples of leaves from a cultural practice experiment at Manjimup were analysed for chloride, total sugars and nicotine. The cultural practices involved several cover crops, plant spacings, addition of nitrogenous fertilisers, topping and not topping. The repeated occurrence of 2 and 3 fold differences in analyses of replicate samples will considerably complicate the interpretation of these results.

(b) 144 samples of leaves from a glass house trial at South Perth were analysed for nicotine and total nitrogen. In this trial there were two levels of nitrogen in the nutrient solution and the quantity of nutrient solution reduced in 3 successive stages after flowering. Potassium and chloride were also supplied at two levels in the nutrient solution. The leaves were taken for analysis from the 1-8, 9-15 and 16-22 positions. Nitrogen and nicotine were found to

(i) increase with added nitrogen and decrease with the reduced rate of nitrogen supply after flowering,

(ii) to increase appreciably from leaf positions 1-8 to leaf position 16-22, and

(iii) to generally slightly decrease with added potassium and chloride.

Animal Nutrition.

1. Selenium in Animal Tissue.—Samples of muscle, liver, kidney, sera and brain from sheep orally fed with 5 milligrams of selenium as sodium selenite for a period of 18 months were analysed

for selenium. The results below are the average of five samples of each and show the main accumulation is in the liver and kidney.

Selenium accumulation in animal tissue

	Selenium, Se p.p.m. dry basis
Muscle	0·52
Liver	22
Kidney	9·6
Brain	1·2
	mgm/litre
Serum	0·17

2. Hereford Hair Fading.—Seasonal loss of coat colour of Hereford cattle was again examined to see if there was any relationship between mineral composition of the hair and colour. 20 samples of hair received were grouped into four colours. The average results below showing the grading from red-brown to dull brown show no relationship between the elements analysed for and colour.

Hereford Hair

Colour	Red brown	Ginger brown	Pale ginger brown	Dull brown
	Per cent. as received			
Calcium, Ca	0·25	0·25	0·29	0·27
Phosphorus, P	0·03	0·03	0·04	0·03
	Parts per million			
Cobalt, Co	0·04	0·07	0·05	0·06
Copper, Cu	5·8	6·4	5·9	6·2
Selenium, Se	0·23	0·25	0·23	0·22
Zinc, Zn	149	147	151	150

3. Fluorosis.—Several samples of bone from cattle on properties at Byford were found to be very high in fluorine. Fluorosis was suspected because of lameness in the cattle and also because the location of the properties relative to a brickworks was similar to that at Armadale, where a fluorosis problem occurred several years ago. A sample of pasture from one property at Byford had 72 ppm of fluorine which would be sufficient to cause fluorosis in stock grazing continuously on this pasture.

12 samples of urine from cows on one property were analysed for fluorine but the levels did not confirm fluorosis in the animals. However our previous experience has indicated that urinary fluorine levels are not necessarily positive indicators of fluorosis.

4. A number of miscellaneous livers, tissues and calculi were received for analysis from a number of diagnostic problems from the Department of Agriculture, Animal Health Laboratory.

Miscellaneous.

1. Spectrography.
   - (a) Emission spectrography. Complete semi-quantitative spectrographic analyses were made on a number of gold ores, lead ores, copper ores, barytes, speiss and miscellaneous minerals.
   - (b) The value of the technique of atomic absorption spectroscopy shown by the instrument we made ourselves justified the purchase of a commercial instrument this year. This is now used for a range of analyses. The versatility of the commercial instrument has been extended by incorporating a physical chopper in the light path and using the instrument as a flame photometer. A method for thallium has been developed using this procedure.

2. Blood alcohol.—Continued excellent agreement between the method used by the Food and Drug Division and the Kozelka and Hine method used in this Division was found on 55 samples of post mortem bloods.

3. Oil seeds.—27 safflower seeds and 266 linseeds were examined mainly for oil content and iodine value.

In the estimation of oil content of large numbers of oil seed samples one of the time consuming and laborious steps is the hand grinding of the sample with the chloronaphthalene-bromonaphthalene solvent. As the method requires 2.5 grams of seed to be completely extracted with 5 mls. of solvent mechanical grinding with sufficient speed has been found unsatisfactory although a variety of different mechanical grinding devices have been tried. This year one of our technicians, Mr. Laidlaw, made a very effective grinding device which is attached to a standard ¼ in. electric drill. This grinder which is a clever modification of a larger commercially available grinding unit has proved very satisfactory. It is convenient to use, much faster and less laborious than hand grinding and also gives more readily reproducible results.

4. Gossypol in cottonseed.—Because of interest in cottonseed meal being produced for stock feed, from the Ord River, a local firm was interested in seeing if their counter current solvent extraction process would remove gossypol from cottonseed meal. Gossypol is very toxic to poultry, only 0.02 per cent. free gossypol can be tolerated in poultry feeds. The usual procedure for overcoming the toxicity of cottonseed is heat treatment, converting the free gossypol to fixed gossypol by combining with protein, but this reduces the availability of the lysine in the meal. Analysis of samples showed that hulled cottonseed meats contained 1.00 and 0.84 per cent. total and free gossypol respectively. The solvent extraction process reduced this to 0.5 and 0.01 per cent. without significantly lowering the available lysine.

5. Soya beans.—Investigations were made for the same firm as in 4 above on the effect of their solvent extraction process on antitryptic factor activity, urease activity, available lysine, total and available methionine in soya bean meal. Each of these characteristics is used for the chemical evaluation of soya bean meal as a poultry food supplement. In each case the determination of each of these characteristics proved to be a more difficult problem than was expected from published methods. Trypsin inhibition was found to be lower in the extracted meal. Urease activity was found to be very low both in extracted meal and in a commercial comparison sample. Available lysine was found to be high in both extracted and commercial meal. Total methionine was approximately the same in extracted and commercial meal but available methionine was higher in the extracted meal.

6. Industrial effluent-ocean outfall.—Investigations were made with the Public Works Department in February and in June of the effluent from a titanium pigment plant at Bunbury. Visual observations had shown that an area of water around the outfall was discoloured and it was thought that this could affect fish life. Ocean samples around the outfall and from areas just inside and outside the affected area were taken for analysis. Examination of these showed that only in an area of about 40 yards radius around the outfall, where the acid effluent was not neutralised, and in a bright orange band about 20 yards wide around this area and extending north and south for about ½-¾ mile was there any likelihood of a hazard to fish life. Even in the bright orange area of precipitation of iron hydroxide water samples only contained 2-3 ppm. of total iron and this was in a flocculent form that readily settled. The large area of pale brown discoloured water extending about 1½ miles seawards and 3 miles north and south contained only 0.1-0.5 ppm. of total iron and showed no evidence of being detrimental to fish.

Subsequent lagooning of the effluent on the shore and allowing it to seep through the sand to the ocean had considerably reduced the area of discolouration. Continued regular inspection of the effluent is necessary to see that no nuisance is created in the area as a few observations are insufficient to predict what will happen with seasonal variations in ocean currents and winds.

7. Corrosion, Scales and Deposits.
   - (a) Wrought iron steam pipes at the Government Printing Office were found to be rapidly corroding, due to air being sucked

back into the lines during night time shut down of the boilers. Condensate saturated with oxygen laying in the steam lines was causing the rapid corrosion. Recommendations were made to use a filming amine in the boiler to protect the steam lines.

(b) Because of high alkalinity scheme water at Port Hedland scale deposits in the air conditioning plant condenser were excessive, even after base exchange softening of the water, as the base exchange softener did not completely soften the water over its whole softening period. Acid addition is the recognised treatment for this problem but, unless carefully controlled, can be even more hazardous. Threshold treatment of the softened water with polyphosphates was found satisfactory in preventing the scale forming.

(c) An unusual deposit that blocked the pipes from a bore providing cooling water for a factory at Melville, was found to be an organic iron deposit formed by iron bacteria from the high iron content of the bore water. The soft deposit had reduced 3 in. diameter pipes to about ½-¾ in. Recommendations were made on physical and chemical removal of the deposit and on periodical shock dosing of the bore with chlorine to prevent a regrowth of the deposit.

(d) A hard black and slimy off-white deposit on a badly corroded copper filter from a bore at North Fremantle was received for examination. This showed the black deposit to be copper sulphide from hydrogen sulphide in the water attacking the copper and the slimy off-white deposit was elemental sulphur deposited by sulphur bacteria oxidising the hydrogen sulphide in the water to sulphur. Recommendations were made on altering the metal of the filter and on aeration of the water to remove hydrogen sulphide to prevent attack on subsequent copper fittings.

(e) The rapid corrosion of a low pitched galvanised roof under the air conditioning cooling tower at the Shenton Park annexe of the Royal Perth Hospital was found to be primarily due to faulty design. The roof which had sagged in places, due to damage during the construction of the tower, was found to contain pools of water which were high in salt from spray from the cooling tower. These pools of saline water were responsible for the rapid attack on galvanised iron. Recommendations were made to prevent a recurrence of the problem.

(f) An investigation was made into a serious corrosion problem of copper pipes at the Tuart Hill High School swimming pool. Copper pipes embedded in concrete between the pool and the filter had been reduced in thickness until they had pitted through at the entrance to the filters. Examination of the corroded pipes showed a thin non adhesive red film of cuprous oxide over badly erosion-corroded metal. This was indicative of slightly acid, high oxygen and high velocity water attack. Analysis of the pool water showed that there had been insufficient control of dosing of the water. The pH had dropped to 5.0 and there was 5 ppm. of copper in the water representing about 7½ lbs of copper dissolved from the copper pipes. Although daily pH control of the water had supposedly been made, the absence of sufficient reserve of alkalinity in the water to cope with the high chlorine dosage would cause the pH to drop rapidly again. For economy in construction, the diameter of the copper pipes had been reduced and this had increased the velocity of the water in the pipes to 13 feet per second compared with the normal design velocity of 5-8 feet per second. With correct pH and alkalinity control the higher velocity water would not have been detrimental. Recommendations were made on better pH control and also on alkalinity control so that a repetition of the previous conditions would be unlikely.

(g) Miscellaneous samples of corrosion deposits and scales were also received from water supply mains at Leighton and Crawley, Narrogin District Hospital, Home of Peace Subiaco, a biscuit factory at Fremantle and irrigation pipes at Argyle. Identification of the deposits and their probable cause was made in each case and where possible recommendations were made to prevent a recurrence of the trouble.

ENGINEERING CHEMISTRY DIVISION.

Introduction.

In discharging its functions of carrying out research into the development and industrial utilisation of the natural resources of the State with emphasis on mineral wealth, and rendering technological and technical asistance to prospective as well as to established industries, some original research and development projects were undertaken by the Division during the year. Of these, work on the process for upgrading local ilmenite, was finalised; work on the utilisation of iron oxide by-product from the above process was continued from the previous year; investigations into utilisation of titaniferous magnetite deposits containing vanadium were initiated during the year.

A larger proportion of time was, however, spent on a number of sponsored projects, undertaken as bench and pilot plant scale investigations, at the request of private interests. In addition, on a number of occasions, free oral advice has been given to other government Departments and to industrial undertakings.

During 1964 the staff of the Division remained static consisting of Divisional Chief, 3 graduate professional officers and a supporting staff of 9 of which 5 officers were on the permanent staff and 4 on the wages staff.

Further Investigations into the Process of Upgrading Ilmenite.

These investigations were conducted for a short period with a view to rounding off the work done previously. Some of this was sponsored by a local ilmenite industry and the results are confidential and are not reported here.

In the course of investigations it was noticed that the activity of char used in the reduction of ilmenite deteriorated with repeated use on recirculation. It was shown experimentally that the value of Collie coal char as a reducing medium deteriorated on heating. Char produced in the pilot plant retort at 700°C was further heated at 1000°C for different periods and then used for reduction of ilmenite in the vibrating sagger. The results are summarised below:—

Metallisation of ilmenite after 23-minute reduction at 1000° C.

Char	Per cent.
Original 700° C. char	21
Original 700° C. char heated for 15 min. at 1000° C.	13·6
Original 700° C. char heated for 30 min. at 1000° C.	9·5
Original 700° C. char heated for 45 min. at 1000° C.	5·6

Normal tests of reactivity towards CO_2 and H_2O did not reveal much difference between the fresh and heated char indicating that there are obviously other factors influencing the value of the char as a reducing medium for iron oxides.

In order to obtain some clarification, further reduction tests were conducted and yielded some interesting results, given below:—

Reducing medium	Metallisation of ilmenite Time Min.	Per cent. metallic iron
6 grams of ilmenite—		
CO, 1400 ml/min.	23	2·0
CO, 800 ml/min.	10	2·7*
H_2, 800 ml/min.	16	32·0
Char produced at 700° C.	23	26·4
Char produced at 700° C., reduction under vacuum	23	13·4
Char produced at 700° C., reduction with addition of N_2 1400 ml/min.	23	14·2
Char produced at 700° C., reduction with addition of N_2 800 ml/min.	23	19·7
Char produced at 700° C., heated to 1000° C.	23	12·1
18 grams of ilmenite—		
CO, 800 ml/min.	15	1·26*
H_2, 800 ml/min.	16	17·3

* No CO_2 could be detected in the off-gas after about 10 minutes.

From the above figures it can be seen that carbon monoxide is a much inferior reductant for local ilmenite than is hydrogen, and that the volatiles of the char appear to be an important factor in the reduction of ilmenite since reduction in vacuum, the addition of nitrogen during reduction and preheating of char all have an adverse effect on the efficiency of the reduction.

It is of interest to recall that in the past, unsuccessful attempts were made to restore the activity of recycled char by addition of various chemicals. It was observed that in general, the addition of chemicals to the char and ilmenite mixture tended to lower the degree of metallisation.

The features of the whole process for upgrading ilmenite were outlined and the results of research and development work on this process were summarised in the paper prepared for presentation and discussion at the 1964 Annual Conference of the Australasian Institute of Mining an Metallurgy.

Apparatus for Continuous Determination of Metallic Iron Content of Reduced Ilmenite.

In connection with the operation of the ilmenite upgrading process on a large pilot plant scale, consideration was given to the possibility of continuous determination of the metallic iron content in reduced ilmenite in a relatively simple way.

Two methods were investigated.

Firstly, it was shown that the metallic iron content of reduced ilmenite was indicated by allowing reduced ilmenite to flow between two electrodes with constant applied voltage. The variations in current flowing between the electrodes was found to follow closely the variations in the metallic iron content of the prepared mixture of ilmenite and reduced ilmenite, provided that the carbon adhering to the ilmenite particles was removed prior to measurement, and the density of the charge was kept constant.

Secondly, it was shown that the metallic iron content was similarly indicated by the magnetic permeability of the sample. This was measured indirectly by allowing reduced ilmenite to flow as a core through transformer windings, provided the conditions mentioned above were maintained.

Since the application of the second principle was considered more advantageous, a simple apparatus, shown in Fig. 1, was developed.

It was shown that, provided the applied voltage was kept constant, the meter could differentiate between samples differing by less than 0.1 per cent. metallic iron. Further improvements in sensitivity were effected by using higher current frequencies. However, for such a set-up a high frequency generator and preferably an oscilloscope would be required, which may be an unnecessary complication for an industrial apparatus.

Upgrading of Ilmenite from the East Coast of Australia.

At the request of a beach minerals industry on the east coast of Australia, investigations were carried out to ascertain the feasibility of upgrading ilmenite from the eastern coast by the process developed by the Division.

Since this ilmenite generally contains more chromium than is acceptable for pigment production, it was in particular desired to establish the behaviour of chromium, and its distribution in the final products of upgrading. Though the iron content and the ratio of Fe_2O_3 to FeO in this ilmenite are similar to those in Western Australian ilmenite from Capel, its titanium oxide content is appreciably lower owing to larger amounts of other constituents, such as chromium oxide, alumina and magnesia.

No difficulties were experienced in applying the upgrading process to this sample of ilmenite.

Upgrading of Leucoxene.

The possibility of upgrading leucoxene by the process developed by the Division for upgrading ilmenite, was investigated by the Division on a bench scale in 1961 and 1962 at the request of a local industry.

At the request of the same Company, this work was resumed in the last quarter of 1963, and was carried over into 1964. The Division was asked to process a larger quantity of the leucoxene in the pilot plant in order to obtain basic data for the estimation of the cost of production.

After processing the required quantity of leucoxene, a plant lay-out for two capacities was prepared, the cost of equipment ascertained, the capital costs estimated and the cost of production of upgraded leucoxene calculated.

In connection with this work an X-ray diffraction spectrometer was used (courtesy of the Physics Department of the Perth Technical College) to determine the iron content of various fractions of reduced leucoxene. Determinations of iron-content by this method were shown to be much too inaccurate, the spectrometer model being a small qualitative instrument rather than an accurate analytical set.

Production of Metal Powder from Iron Oxide.

Among several possible uses for the iron oxide produced as a by-product in the process for upgrading ilmenite, its direct reduction to metal powder, suitable for powder metallurgy, appeared most attractive. Investigations along these lines were started in the second half of 1963, and were continued in 1964. Main efforts were directed towards the elimination of excess titania from the oxide product, designing and building the pilot plant for reduction and the production of metallic powder for experimental purposes.

By sampling and analysing the oxide produced in different stages of aeration of ilmenite, of leucoxene, and of that from the pressure-steam treatment of ilmenite (with hydrogen evolution), it was established that no significant variations in TiO_2 content of the oxide product occurred during aeration, the average for ilmenite aeration being 3.7 per cent., for leucoxene aeration 2.3 per cent. and for ilmenite treatment with steam under pressure 5.3 per cent. TiO_2.

These results indicated that the TiO_2 content of the oxide product cannot be lowered by discarding a portion of the product of aeration high in TiO_2, the latter being not produced chemically but originating from abrasion of ilmenite (or leucoxene) particles. This conclusion was supported also by the facts that earlier tests for lowering the TiO_2 content by formation and separation of γ hematite (magnetic), showed that magnetic fractions contained the same amount of TiO_2 as the original iron oxide.

Similarly, the residue from selective leaching tests with sulphuric acid and fluoride showed no significant changes in TiO_2 content.

An attempt was made to separate the TiO_2 richer portions of the oxide by treatment in hydroclones. A series of tests was conducted using a small laboratory glass hydroclone unit (15 mm size) with the following variables: feed rate (controlled by pressure), size of vortex finder and apex cone, solids content of the feed slurry, and re-treatment of top product up to six times.

Although a limited separation could be achieved, a significant removal of TiO_2 appeared impossible in this way.

Further attempts to reduce the TiO_2 content, were made using (a) wet magnetic separation and (b) Wilfley table specially fitted with electromagnets beneath the wooden table. Neither attempt was encouraging, the failures being attributed to the extreme fineness of the material.

In connection with the problem of feeding such a fine material into the reduction unit, and its fluidisation or entrainment in the unit, the following tests were carried out:

Samples of oxide were dried in (a) a laboratory oven and (b) in the spray drying unit.

Tests indicated that the particle sizes ranged from 40μ to less than 2μ, the specific surface areas from 9000 to 19000 cm^2/gm, and that there was not much difference between the particle sizes of spray dried and oven dried products.

Entrainment tests were conducted in a vertical tube 4 ft. long and 0.8 in. internal diameter using air as entrainment medium. Indications were that 50 per cent. of oven dried oxide could be entrained at an air velocity of 1.5ft./sec.; complete entrainment required an air velocity of 5 ft./sec. Tests with spray-dried oxide were less successful, as, though completely dry, it was sticky, tending to agglomerate and accumulate in the feeder and the tube bends, also blocking the recovery cyclone. It was concluded that the spray-drying apparently produced undesirable characteristics of the powder.

Calculations using the data in the literature showed that for a 50μ particle at 700°C, in hydrogen containing 25 per cent. of the equilibrium concentration of water vapour, the time for 99 per cent. reduction is approximately 18 seconds. Accordingly, an indirectly heated entrained bed tube reactor was envisaged for actual reduction experiments.

When exploring the methods of feeding the fine material into the reactor, difficulties were experienced with maintaining a uniform feed rate with a vibrating tray feeder. Other types of feeders such as screw feeder, air jet feeder and various combinations of these types, were tested. However, a uniform feed rate, essential for operation of an entrained bed reactor, could not be obtained.

This led to the development of an unusual "brushed-screen" feeder shown diagrammatically in Fig. 2, which was built and later incorporated into the pilot plant reactor.

As exploratory tests, iron oxide was reduced in small batches (10-20g) in a small stainless steel pot, heated in an electric furnace and vibrated continuously during processing. Hydrogen was blown through a stainless steel tube into the bottom of the oxide bed, causing partial fluidisation. Reductions were made at 500°, 600°, 700°, and 800°C with various amounts of hydrogen passed through the charge.

Maximum metallic iron content achieved was 87.5 per cent. representing almost complete reduction of iron oxide. The powders obtained were strongly pyrophoric, but could be successfully passivated by contact with nitrogen at 700°C for a relatively short time (20 min.) immediately after reduction.

Briquettes made from powder produced by reduction of the oxide at 700° and 800°C, had a sp. gr. between 4.2 and 4.5 at a briquetting pressure of 45,000 $lb./in.^2$.

Further batches of about 100g. dry oxide were reduced later to provide sufficient metal powder for tests on the possibilities of separation of TiO_2 after reduction.

Analysis of size fractions of the product obtained by reducing the oxide at 700°C indicated that the distribution of iron and titania in these fractions was uniform throughout the size range, confirming that no separation of TiO_2 was possible employing mechanical means.

The pilot entrainment reactor designed for a total entrainment path of 60 ft. and giving a solids residence time of up to 20 seconds, was constructed using concentric stainless steel tubes ⅞ in. and 1½ in. in diameter, respectively, with an up-flow through the inner tube and down-flow through the annular space between the tubes.

Preliminary trials showed that the arrangement and mounting of the gas preheater was unsatisfactory. The bottom section of the reactor was modified, and the design of the solids feeder was improved to provide better gas sealing. The final arrangement of the reactor is shown in Fig. 3.

Up to the end of the year a small series of tests was carried out in this reactor.

Working temperatures of 500°, 600°, and 700°C could be maintained with reasonable uniformity over the whole length of the shaft.

However, blockages occurring in the "off-vertical" section of the main entrainment tube, immediately above the solids feed point, prevented operation of the unit for longer periods than about 30 minutes.

In connection with this, further information on the entrainment behaviour of the oxide product in tubes in slightly off-vertical position, was sought. This was examined visually in a glass tube of 2 in. diameter and 4 ft. long, where the effect of sloping the tube at various small angles from vertical, was studied.

The work on this project was discontinued by the end of the year, and will be resumed when the opportunity occurs.

Utilisation of Titaniferous Magnetite Deposits Containing Vanadium at Coates Siding.

Following the relinquishing of temporary reserves for exploration for vanadium ore deposits granted to a subsidiary of an overseas firm, investigational work concerning one of the deposits, situated near Coates siding, about 3 miles east of the Wundowie Charcoal Iron Works, was considered.

This deposit consists of gabbroic and anorthositic rocks containing disseminated titaniferous magnetite averaging 0.47 - 0.65 per cent. vanadium pentoxide. It is estimated to contain 8.2 million tons of weathered rock and possibly over 32 million tons of original gabbroic rock (ore).

The problem was formulated as follows:—

> How can the deposit be economically exploited for industrial purposes, considering that the Wundowie Charcoal Iron Works are situated at an economic hauling distance of raw materials, the diversification of the production of these works being desirable in view of the advent of another, larger, iron and steel industry in this State.

Since the direct use in blast furnaces of a magnetite concentrate from this deposit would be difficult owing to the presence of appreciable amount of titanium dioxide in the ore, the necessity for investigations on laboratory and pilot plant scale was indicated. These were initiated in the first half of 1964.

It was also agreed that C.S.I.R.O. Secondary Industries Laboratories in Perth would undertake research into the possibility of more economic extraction of vanadium oxide; work which would probably involve long term fundamental laboratory investigations.

Description of the deposit:—The original outcrop of titaniferous magnetite rock, bearing vanadium, is a zone some 5,200 ft. long and 250 to 500 ft. wide, the top of the ridge being some 400 ft. higher than the valley on either side.

The deposit is blanketed by a 12 ft. thick laterite cap. On the top of the ridge, immediately beneath the laterite cap is 3 to 5 ft. of tan to brown clay material. Beneath the clay there is about 80 ft. of soft rock, weathered in situ. This is underlaid by a large deposit of unaltered gabbroic and anorthositic rock, containing disseminated magnetite.

According to the minerals identification made by Mineral Division in 1963, a sample of unaltered rock contained the following minerals listed in order of relative abundance.

Magnetite (intergrown intensively with fine lamellae of ilmenite), plagioclase, hornblende, ilmenite (as discrete grains), chlorite, epidote, altered pyroxene, pyrite, chalcopyrite, hematite and biotite.

A sample of unaltered rock was analysed by Australian Mineral Development Laboratories at the request of C.S.I.R.O. Secondary Industries Laboratories, with the electron probe micro-analyser, which revealed a constant concentration of vanadium in the magnetite with a negligible concentration in the ilmenite.

Assays of individual samples taken at 5 ft. intervals through the weathered zone, showed only minor variations in vanadium, iron and titanium contents.

The analyses of bulk samples of weathered and unaltered rock and of a representative sample of cap rock (0-12 ft. level) are shown in the table below.

Sample	Level	Iron, Fe	Titanium, Ti	Vanadium, V
	Ft.	Per cent. on dry basis		
Cap Rock	0–12	40·6	4·45	0·44
Weathered Rock	17–95	32·2	4·46	0·40
Unaltered Rock	below 95	27·5	3·55	0·29

Treatment of unaltered rock (ore):—Preliminary tests showed that approximately 40 per cent. by weight of the unaltered rock can be separated as a magnetic fraction containing a large proportion of the iron, titanium and vanadium present in the original rock. Among the magnetic and gravity type separations tested, the best concentrate was obtained using wet magnetic separation.

From the rock crushed — 35 mesh Tyler S. S., the following concentrate was obtained:—

	Assay Per cent.	Recovery Per cent. of feed content
Total weight	....	37
Iron, Fe	58·0	78
Titanium, Ti	6·58	68
Vanadium, V	0·81	over 90

From the above assay figures, a probable composition of the concentrate was calculated as follows:—

	Per cent.
Magnetite, Fe_3O_4	69·5
Ilmenite, $FeO.TiO_2$	20·8
Vanadium oxide, V_2O_3	1·2 (V_2O_5 1·45)
Gangue (by difference)	8·5

In order to have some indication of the behavour of the material when subjected to the reduction-aeration process, several batches of 250g of the above magnetic concentrate were metallised using Collie coal char as reducing agent. Char and concentrate mixture was heated in closed containers at 950° and 1,100° C. for periods of 2 to 4 hours, and the metallised product separated magnetically.

The reduced concentrate assayed:

	Per cent.
Total iron, Fe	77·7
Metallic iron, Fe	75·8
Titanium, Ti	7·56
Vanadium, V	1·14

Metallisation of the iron was thus 97.5 per cent.

Reduced concentrate was aerated by the procedure normally employed in the process for upgrading ilmenite.

From 100g reduced concentrate, the following products were obtained.

	Weight, g.	Assay, per cent. Fe	Ti	V
Residue	17	17·5	25·9	0·77
Iron oxide	118	58	2·05	0·56

Distribution of the constituents:

	Per cent. Fe	Ti	V
Residue	4	64	14
Iron oxide	96	36	66

Approximately 20 per cent. of the total vanadium remained dissolved in the final liquor which was coloured blue ($VOSO_4$).

Over 80 per cent. of the non-magnetics from magnetic concentration of the original rock was found to become magnetic to some degree after reduction roasting, probably due to the reduction of iron oxides in iron bearing silicates. Total iron determined in this product was approximately 5 per cent. and silica 50 per cent., the vanadium content being insignificant.

Salt-roasting and leaching tests for vanadium extraction were made with 1.5g and 5g batches using — 200 mesh concentrate. Roasting was carried out with the following additives: NaCl, Na_2SO_4 or Na_2CO_3 at temperatures ranging from 600° to 1,000° C. Solids were then leached with hot water (near boiling), and vanadium determined in the extract.

Although the results were somewhat variable, it was apparent that Na_2CO_3 was the most effective additive.

In general, increased proportions of additives and increased temperature of roasting gave increased water solubility of vanadium, the best result being 90 per cent. extraction of vanadium into water after roasting with 40 per cent. Na_2CO_3 at 1,000° C. for one hour.

Recoveries from NaCl roasts were improved by roasting at temperatures above 1,000° C., but even after one hour at 1,300°C. with 13 per cent. NaCl addition, only 40 per cent. of the vanadium was water soluble.

Pre-oxidation of the magnetite to hematite in the concentrate, prior to the salt roast, had very little effect on recoveries of vanadium.

Magnetite concentrate, crushed to — 100 mesh Tyler S. S. was leached with 5 per cent. NaOH solution at 170° C. and 100 lb./sq. in. pressure for four hours. No vanadium was found to be dissolved. However, a similar leach of pre-oxidised material dissolved 27 per cent. of the total vanadium, showing that some vanadium was made available by the oxidation of magnetite to hematite.

Treatment of weathered rock (ore).—Laboratory decantation and elutriation tests showed that some concentration of iron, titanium and vanadium could be obtained by gravity separation. One test over the Wilfley table yielded a heavy fraction containing 80 per cent. of the vanadium in 57 per cent of the original weight. Similarly, a concentrate produced in a laboratory sink-float separator contained 75 per cent. of the iron, titanium and vanadium of the feed in 50 per cent. of the original weight, and assayed:—

	Per cent.		Per cent.
Iron, Fe	48·0	equivalent to Fe_2O_3	68·0
Titanium, Ti	6·7	„ TiO_2	11·0
Vanadium, V	0·6	„ V_2O_5	1·07

Wet and dry magnetic separations were unsuccessful on weathered ore. However, some concentration was obtained by magnetic separation after a magnetising roast of the ore, to convert iron oxides to magnetite. A strongly magnetic fraction containing 90 per cent. of the vanadium in 54 per cent. of the feed weight was obtained in one experiment.

A number of bench scale roastings with NaCl, Na_2SO_4 and Na_2CO_3 as additives was made at 1,000° C., the maximum recovery of water-soluble vanadium being 60 per cent.

The ore ground to — 100 mesh Tyler S. S. was leached under pressure, as mentioned under the treatment of unaltered rock. Vanadium extraction was 14 per cent. of the total.

The solid residue was separated into light, medium, and heavy fractions and these assayed for vanadium.

It was apparent that most of the leaching had taken place from the light, fine material, leaving heavy, coarse material unattacked.

Two samples, one mainly clay from 12-17 ft. level, the other from the 17-95 ft. level bulk sample, were made into bricks and fired at 1,000° C., 1,100° C. and 1,350° C. Both samples showed some potential as brick-making material.

All the above tests were made in the course of preliminary exploratory investigations intended to clarify further attack. It was directed primarily towards establishing the best method of ore concentration.

The work is to be continued in 1965.

Preparation of Fertilizer Pellets.

It was suggested by the Division in 1963 that rock phosphate-sulphur pellets might be a cheap substitute for superphosphate. It was further suggested that the addition of up to 20 per cent. of superphosphate to pellets would be advantageous as this would give the plant a ready supply of soluble phosphate in its early life.

A search of the literature revealed that Dr. Swaby of C.S.I.R.O. in Adelaide had already made some bench scale tests along the similar lines. Contact was made with Dr. Swaby, and an attempt was made to obtain the co-operation of the W.A. Agricultural Department for conducting larger scale trials here.

In the second half of 1964 the Division was approached by the C.S.I.R.O. Regional Laboratory enquiring the possibility of the Division preparing a larger amount of pellets for fertiliser trials.

About 6 cwt. of pellets were made from a mixture of four parts rock phosphate, one part superphosphate and one part sulphur.

The pelletiser, specially built for this purpose, consisted of a drum 4 ft. 9 in. long and 15 in. diameter, revolving at 40 r.p.m. Dry mixture was fed into the drum by a vibratory feeder and moistened by a fine water spray. Oversize and undersize pellets were separated by screening, disintegrated and recycled to the pelletiser. Pellets of the order of — ¼ in to + 1/16 in. were dried and bagged.

It was noticed that properly moistened material fed into the pelletising drum in a direction of movement along its longitudinal axis, on touching the wall (turning at right angles to the motion of the feed) immediately rolled up into pellets. This is thought to be a way of greatly increasing the capacity of drum pelletisers.

Beneficiation of Calcareous Beach Sand.

As mentioned in the Annual Report for 1963, a four-stage plate electrostatic (high tension) separator was built by the Division for larger scale beneficiation work, Fig. 4. In the second half of 1963, this separator was loaned to an industrial firm for pilot plant operation, the staff of the Division acting as consultants.

This work was continued into 1964 until the firm built its own separator, returning the loaned one.

During initial testing, some modifications were made to the design of the separator, and it was also found that the unit could handle higher feed rates than had been the case in small scale tests.

The operation of the separator confirmed the observations made previously, that the method of heating the sand prior to treatment in an electrostatic separator, has a profound influence on the efficiency of separation of silica from carbonates, indirect heating giving consistently good results. Since, however, direct heating has distinct advantages over indirect heating when waste heat is not available, more work was carried out by the Division into this aspect during the year.

For this purpose the single stage separator, also built by the Division, was further modified and adapted for smaller scale work.

No definite conclusions could be made at the end of the year, the work being still in progress.

However, one fact emerged, viz., that even with indirect heating, it was possible to render the sand inert to electrostatic separation by using too high a contact temperature, of the order of 400°-500° C. or higher.

Production of Lightweight Aggregate for Concrete.

At the request of a local industry the possibility of production in a rotary kiln of lightweight aggregate for concrete from pelletised local clay, was investigated.

The results indicated that owing to agglomeration at bloating temperatures, it would be difficult to process pellets from the clay supplied in the rotary kiln using straightforward methods.

Satisfactory results may however, be expected when refractory powder is sprayed into the hot zone of the kiln, the method first used in the U.S.A. and tried out in Australia by C.S.I.R.O. Division of Building Research.

Production of Hardened Raw and Metallised Pellets from Local Iron Ore.

Having built a drum pelletiser for the preparation of fertiliser pellets, the preparation of iron ore pellets was briefly investigated.

Hardened raw ore pellets and metallised pellets from Robe River (Pilbara) ore and Yampi Sound ore were prepared for demonstration purposes. The analyses of the pellets were:

	Total iron, per cent.	Metallic iron, per cent.
Robe River, raw, hardened	65·4	....
Robe River, metallised	90·1	90·0
Yampi Sound, raw, hardened	70·1	....
Yampi Sound, metallised	98·2	98·0

Recarbonation of Hydrated Lime.

At the request of a local firm investigations into possibility of re-carbonating hydrated lime for special purposes were commenced towards the end of the year. This work is still in progress.

Production of Antimony Oxide.

Advice was given to a local industry on the production of antimony oxide from local raw material. The necessary equipment for oxidising antimony ore in an entrained bed was loaned to the interested party.

Cleaning of Iron Chips.

Cleaning of locally produced iron chips from the manufacture of nails was briefly discussed with a local enterprise. It was shown that saw dust and kerosene can be removed from chips by abrasion with calcareous beach sand followed by screening and winnowing. The result of this discussion and advice, is that locally produced chips are now being utilised for concrete surfaces, making them non-slippery. Previously all the requirements were said to be imported from the Eastern States.

Beneficiation of Local Low Grade Manganese Ore.

In order to round off the work done in previous years on upgrading low grade manganese ore from Ripon Hills (Pilbara) and Ravensthorpe areas, the work was resumed for a short period during 1964.

Magnetic separation after a reducing roast, produced upgrading superior to that previously obtained (Annual Report 1961). This was thought to be due to the improved magnetic separation obtained with the new disc separator built, by the Division in the previous year. Fig. 5.

Further trials using the reduction-aeration technique similar to that used for upgrading of ilmenite were conducted along two lines, viz.:

(a) low temperature reduction, around 450° C., followed by normal aeration for "rusting out" manganese, and

(b) normal reduction, around 800° C., followed by aeration at high pH value (8-9) in order to rust the iron in situ.

The results of both tests were discouraging since little separation was achieved. The operation appeared unlikely to be workable.

From the investigations carried out by the Division, it can be concluded that the technique most worthy of further examination is magnetising roasting, and that a process based on reduction followed by aeration gives little promise for beneficiation of manganese ores similar to those tested.

Calcining of Magnesite.

At the request of a local industry additional work on calcination of magnesite, originally carried out in the previous year, was done.

Lumps of local magnesite (½ in. and 1½ in.) were calcined in an oil fired furnace at 1,300° and 1,500° C., and the results evaluated.

General.

(1) A paper entitled: "A New Process for Upgrading Ilmenitic Mineral Sands", by R. G. Becher, R. G. Canning, B. A. Goodheart and S. Uusna, was prepared for presentation and discussion at the 1964 Annual Conference of the Australasian Institute of Mining and Metallurgy, held in Perth. The paper was presented by Dr. S. Uusna on the 23rd August.

The paper was recommended for publication in the Proceedings of the A.I.M.M. and will probably appear in print during 1965.

(2) The Division provided the relevant portion of a paper from the Government Chemical Laboratories to the 1965 Chemical Engineering Conference in Sydney, commemorating the 50th Anniversary of Chemical Engineering in Australia, organised by the Institution of Engineers, Australia.

(3) During the year, the heavy-media separator and a bench scale jig (Denver) were transferred from the Industrial Chemistry Division to this Division.

The equipment was overhauled, modified, installed and commissioned. A model of a four-stage pulsed column was built and incorporated into the jig set-up. The evaluation of the performance for the combination of jig and pulse-column is still to be made.

(4) A Humphreys spiral concentrator with 2 ft. diameter spiral launder, made of fibre glass, was acquired at the end of the year and will be installed in 1965.

(5) Chemist and Research Officer, Grade 1, Mr. R. G. Becher, was granted leave of one year's duration, starting this by the end of the year.

(6) The following interstate and overseas visitors visited the Division during the year:—

Mr. J. A. Schmidlern, Assistant General Manager, American Cyanamide Co., Pigments Division, U.S.A.

Mr. A. Silkin, General Purchasing Agent, Inorganic Chemicals, American Cyanamide Co., Purchasing Division, U.S.A.

Mr. P. B. Moffitt, Field Engineer, Cyanamide Australia, Pty. Ltd., Mining Chemicals Department, Melbourne, Victoria.

Mr. B. Lees, Technical Service Department, British Petroleum, London, U.K.

Mr. A. C. Gattegno, Technical Service Department, British Petroleum, Head Office, for Australia, Melbourne, Victoria.

Mr. F. A. Ferguson, Stanford Research Institute, Economics Division, Menlo Park, California, U.S.A.

Mr. A. T. Callman, Member of Wards Employment Advisory Board, Darwin, N.T.

Mr. J. T. Richmond, Laporte Industries Pty. Ltd., London, U.K.

Mr. S. Shimazawa, Mitsui & Co. (Aust.) Pty. Ltd., Melbourne, Victoria.

FOODS, DRUGS, TOXICOLOGY AND INDUSTRIAL HYGIENE DIVISION.

As in recent years the greater proportion of the work of this Division in 1964 again consisted of chemical examinations for the Departments of Agriculture, Police and Public Health, as well as for the Milk Board of Western Australia and the Swan River Conservation Board, but the normal variety of miscellaneous work was also performed for other Departments and for the general public. As in 1963 there was a sharp increase in the number of samples received under the classification of Public Pay, chiefly in connection with the medical diagnosis of industrial toxicology.

The staff of the Division was again short of one professional officer throughout the year. As a consequence of the shortage of qualified staff, three technicians (in the course of qualifying) were appointed during the later part of the year, and it is expected that early in 1965 the staff of the Division will number fifteen officers, of which eleven will be qualified chemists.

Some relief in the matter of accommodation has been afforded by the completion, during the year, of a new "Trace Laboratory" which is double the floor space of the previous room and provides working space for four officers.

3,511 samples were received during 1964, being an increase of approximately 50 per cent. during the four years since 1960.

A broad outline of the variations in numbers of samples over the period 1960-64 is indicated in the following classification Table 4.

TABLE 4

	1960	1961	1962	1963	1964
Class—					
Foods—total	369	815	815	656	773
Milks	194	437	574	382	604
Exhibits—alcohol	358	315	331	378	433
Human toxicology	421	388	611	649	604
Industrial hygiene	327	335	446	233	349
Miscellaneous	590	710	608	1,010	883
Pesticides	24	160	231	210	175
Oil seeds	144	174	....	342	143
Pollution Surveys—					
Swan River	204	178	128	128	145
Bunbury	48	50	50	48	48
TOTAL	2,436	2,901	3,177	3,279	3,511

Table 5 shows the source and condensed description of samples received during 1964.

TABLE 5.

FOODS, DRUGS, TOXICOLOGY AND INDUSTRIAL HYGIENE DIVISION.

	Agriculture Department	Labour Department	Mines Department	Police Department	Public free	Public Health Department	Public Works Department	Swan River Conservation Board	Treasury Department	Other Government Departments	Pay					Total
											Department of Air	Hospitals	Milk Board	Public	Other	
FOOD—																
Alcoholic liquor	10	....	....	5	....	1	....	....	....	....	....	....	....	....	....	16
Apples	29	....	....	....	....	1	....	....	....	....	....	....	....	....	....	30
Butter	15	....	....	....	....	....	....	....	....	....	....	....	....	....	....	15
Cheese	49	....	....	....	....	....	....	....	....	....	....	....	....	....	....	49
Grapes	15	....	....	....	....	....	....	....	....	....	....	....	....	....	....	15
Milk	....	1	....	....	....	6	....	....	....	1	....	....	597	....	....	605
Various	2	6	....	....	....	20	....	....	10	3	....	1	1	2	....	45
INDUSTRIAL HYGIENE—																
Air	....	....	10	....	....	94	....	....	....	....	....	....	....	....	....	104
Carbon monoxide	....	....	....	....	....	12	....	....	....	....	....	....	....	....	....	12
Urine	....	18	....	....	....	39	....	....	....	....	....	5	....	160	7	229
Various	....	2	1	....	....	1	....	....	....	....	....	....	....	....	....	4
MISCELLANEOUS—																
Building materials	....	....	....	....	....	38	1	....	....	....	....	....	....	3	1	43
Criminal cases	....	....	....	26	....	....	....	....	....	....	....	....	....	....	8	34
Detergent	....	....	....	....	....	....	....	....	91	....	....	....	....	....	....	91
Disinfectant	....	....	....	....	....	38	....	....	....	....	....	....	....	....	....	38
Oats	12	....	....	....	....	....	....	....	....	....	....	....	....	6	....	18
Oil seed—																
Cottonseed	15	....	....	....	....	....	....	....	....	....	....	....	....	....	....	15
Linseed	128	....	....	....	....	....	....	....	....	....	....	....	....	....	....	128
Oxygen	....	....	....	....	....	....	....	....	....	....	26	....	....	....	....	26
Pesticide	107	....	....	....	....	19	48	....	....	....	....	....	....	1	....	175
Pethidine	....	....	....	....	....	41	....	....	....	....	....	....	....	....	....	41
Polish	....	....	....	....	....	....	....	....	22	....	....	....	....	....	....	22
Waters	....	....	....	....	....	115	....	....	....	....	....	....	....	3	....	118
Various	20	....	8	1	4	32	12	....	16	17	....	3	....	35	1	149
POLLUTION—																
Effluents	....	....	....	....	....	12	....	29	....	....	....	....	....	....	....	41
Maritime	....	....	....	6	....	....	....	....	....	....	....	....	....	....	....	6
Sewage	....	....	....	....	....	1	....	....	....	....	2	....	....	....	....	3
Surveys—																
Bunbury	....	....	....	....	....	....	48	....	....	....	....	....	....	....	....	48
Swan River	....	....	....	....	....	....	....	145	....	....	....	....	....	....	....	145
TOXICOLOGY—																
Human—																
Toxicology	....	....	....	600	....	....	....	....	....	....	....	4	....	....	....	604
Sobriety	....	....	....	202	....	1	....	....	....	....	....	....	....	3	1	207
Traffic death	....	....	....	226	....	....	....	....	....	....	....	....	....	....	....	226
Specimens from patients	....	....	....	....	....	106	....	....	....	....	....	60	....	....	....	166
Animal	28	....	....	3	....	....	....	....	....	....	....	....	....	12	....	43
	430	27	19	1,069	4	577	109	174	139	21	28	73	598	225	18	3,511

Foods.

A total of 773 samples of foods was received for examination during the year, being an increase of 117 over the number for 1963. This was due to the large number of milks submitted by the Milk Board of W.A., 597 as compared with 376 the previous year.

Of this number 347 were samples seized by Inspectors for checking against the standards required by the Regulations under the Milk Act. 6.1 per cent. of these samples contained less than the legal minimum of milk fat (3.2 per cent.), and 60.6 per cent. contained less than the legal minimum of solids not fat (8.5 per cent.), while 73.4 per cent. of the samples failed to comply with the legal standard for freezing point of milk (0.540 degrees Centigrade below zero). The proportion which failed to comply with the standard for fat and solids not fat are somewhere greater than in 1963, but show a slight improvement in respect of freezing point figures. The distribution of analytical figures is shown in the following tables:—

MILK FAT

Per cent. in sample	Per cent. of total samples
Less than 3·00	0·9
3·00–3·19	5·2
3·20–3·49	17·3
3·50–3·74	18·4
3·75–3·99	12·1
4·00–4·99	36·3
More than 4·99	9·8
	100·0

MILK SOLIDS NOT FAT

Per cent. in sample	Per cent. of total samples
Less than 8·00	4·9
8·00–8·24	17·6
8·25–8·49	38·1
8·50–8·74	26·3
8·75–8·99	11·3
More than 8·99	1·8
	100·0

FREEZING POINT

Degrees C. below zero	Per cent. of total samples
Less than 0·510	1·4
0·510–0·519	0·6
0·520–0·529	12·9
0·530–0·539	58·5
0·540–0·550	25·4
More than 0·550	1·2
	100·0

In presenting these figures it is emphasised that these were Inspectors' samples for which there was prima facie evidence of their not complying with legal standards.

An additional 209 samples of milk were also submitted for determination of freezing point only, and 41 samples for analysis for fat and solids in connection with the Board's Milk Improvement Scheme. The distribution of figures for the two groups is shown in the following tables:—

FREEZING POINT—209 SAMPLES

Degrees C. below zero	Per cent. of total samples
0·510–0·519	0·5
0·520–0·529	1·0
0·530–0·539	85·9
0·540–0·550	12·1
More than 0·550	0·5
	100·0

MILK FAT—41 SAMPLES

Per cent. in sample	Per cent. of total samples
Less than 3·00	4·7
3·00–3·19	2·3
3·20–3·49	25·7
3·50–3·74	27·9
3·75–3·99	9·2
4·00–4·99	30·2
	100·0

MILK SOLIDS NOT FAT—41 SAMPLES

Per cent. in sample	Per cent. of total samples
Less than 8·00	4·7
8·00–8·24	4·7
8·25–8·49	16·3
8·50–8·74	53·5
8·75–8·99	11·6
More than 8·99	9·2
	100·0

Forty-nine samples of cheese were analysed for the Dairying Division of the Department of Agriculture as a check on the quality of factory production.

Of this number 48 per cent. contained more than 50 per cent. of fat calculated on the moisture-free basis, compared with 61 per cent. of the samples which complied with this standard in 1963.

Fifteen samples of grapes were received from the Department of Agriculture. Seven samples were analysed in connection with assessment of maturity for the Horticulture Division, and eight samples for the Plant Research Division as a result of "setting" trials involving various kinds of treatment.

The work of the Department of Agriculture on the control of "scald" in apples was continued during 1964, when 24 samples were submitted in connection with ethoxyquin treatment, and five for analysis after diphenylamine treatment.

Wine made from grapes which had been sprayed, experimentally, with three different insecticides was analysed to determine the levels of insecticide present in the finished product, as well as to ascertain the alcohol and sugar contents of the wines for the information of the Agriculture Department's Viticulturist.

Ten samples of foods were received from the Government Tender Board. These comprised eight samples of jelly crystals and two of canned meat which were analysed for compliance with the Food and Drug Regulations and to assess their comparative suitability for use in Government institutions.

Fifteen samples of butter were submitted by the Dairying Division of the Department of Agriculture. Eleven were examined to determine the reaction, pH, of the serum, while on the other four a quantitative estimation of the colour was made in terms of a mixture of red and yellow hues. Information of the variations in colour of normal butter throughout the year and from different localities was considered necessary in order to determine whether or not any specific margarine contravened the Margarine Act Regulations by resembling butter in colour.

Only 27 samples of foods were examined for the Public Health Department during the year, many as a result of complaint regarding a particular article.

A tin of jam contained "gritty particles" which proved on examination to be small crystals of sodium citrate and/or sodium hydrogen citrate. Another sample of jam, while obviously containing fewer fig seeds than would be expected, nevertheless possessed the normal flavour of this fruit as well as other characteristics of the fig.

Samples of sugar used for the preparation of a novelty confectionery were examined to ascertain the nature of the colourings. Three contained artificial dyes not permitted by Food and Drug Regulations. Of two icing sugars similarly examined, one contained a prohibited artificial dye.

Samples described as "plastic icing" were packed in plastic bags which were "swollen" due to internal pressure of gas which was identified as carbon dioxide.

Carbon dioxide gas was also identified as responsible for "springing" of a can of a fruit preserve. No evidence of decomposition was observed nor of corrosion of the can, but there was considerable "spotting" due to removal of lacquer. As with the "plastic icing" it was concluded that partial breakdown of some of the sugar had taken place.

A highly coloured condiment mixture was found to contain only natural vegetable colourings, artificial dyes were absent.

A badly "blown" can of a fish product showed considerable staining of the inner surface of the can, from which most of the tinned surface had been removed. The gas present proved to be approximately 80 per cent. hydrogen and 20 per cent. carbon dioxide with traces of organic gases.

Apples alleged to have been responsible for sickness were examined for insecticide residues but no cause of the trouble could be detected.

Samples of soya bean flour and of a coffee and chicory mixture were the subject of query, but chemical and physical examinations failed to show that either was not correctly described.

A low calorie cool drink was analysed to provide the data for the label as required by the Food and Drug Regulations in respect of this class of beverage.

Samples of pastry and an imported canned fish product were analysed to determine the nature of the preservatives and/or other additives present in the samples.

A complaint that a can of sardines had a "kerosene" flavour led to the examination of other cans of this brand, but the alleged flavour could not be detected, and the absence of any mineral oil was confirmed by analysis.

Further complaints regarding a sample of cauliflower disclosed that both D.D.T. and endrin were present in the raw sample, but neither could be detected in the cooked portion of the vegetable.

Three samples of brandy and one of whisky were submitted by the Liquor Inspection Branch of the Police Department. Analysis confirmed that in all these samples the spirit strength had been reduced below the permitted legal minimum by the addition of water. Another sample labelled "Cherry Brandy" was analysed to provide information as to alcohol content.

Samples of milk from an institution were submitted following complaints of poor quality in regard to "cream" content. Chemical analysis indicated that the complaint was justified.

A sample of soft drink contained obvious foreign matter which proved to be a mould growth, while a sample of beer was found to contain a little of what appeared to be pine oil. It imparted to the beer what was described as "an unusual odour and a very nauseating taste".

Human Toxicology.

Samples were received from approximately 328 cases of sudden death which were the subject of police investigation. One hundred and thirty-five cases were as a result of "traffic accident", while 144 cases, comprising 510 exhibits, as registered, were examined for the presence of poison or other physiologically active drug. Of these 510 exhibits, 36 consisted of a package containing a number of medicinals, bottles of tablets, etc., numbering in all 220 separate objects requiring examination.

In 39 cases no poison or drug was detected while in 104 cases a poisonous substance or other drug was identified on analysis. In a number of cases more than one poison or drug was detected in the exhibits. Details are listed in Table 6.

TABLE 6.

Poison or Drug	No. of Cases
Carbon monoxide	29
Pentobarbitone	26
Amylobarbitone	13
Quinalbarbitone	4
Butobarbitone	3
Phenobarbitone	2
Barbiturate (unidentified)	15
Carbromal	12
Amitriptyline	3
Chloral	4
Arsenic	3
A.P.C.	3
Stychnine	3
Chlorpromazine	2
Librium	2
Stelazine	2
*Various, one of each	9
Negative	39

* Barbitone, bromoureide (unidentified), bromvaletone, cyanide, doloxene, ephedrine, imipramine, megimide, parathion, phentermine (duromine), toluene.

It was noted that carbromal was usually associated with pentobarbitone, being derived from ingestion of "Carbrital."

In 60 of the 109 cases where a sample of blood was available, alcohol was found to be present. The concentration of alcohol in the blood was 0.15 per cent. or greater in 22 of these cases, and 0.05 to 0.15 per cent. in 20 cases.

From another 47 cases of sudden death other than "traffic accident," blood samples were analysed for alcohol making a total of 156 such cases of sudden death where the blood alcohol figure was determined as a routine procedure. The distribution of the blood alcohol figures is indicated in Table 7, from which it will be observed that in 35 cases, i.e., 22 per cent. of the total, the blood alcohol figure was 0.15 per cent. or greater.

TABLE 7.

Alcohol per cent.	No. of Cases
Negative	71
Less than 0·05	22
0·05–0·09	13
0·10–0·14	15
0·15–0·20	18
0·21–0·30	15
More than 0·30	2
	156

Blood Alcohol (Traffic).

Two hundred and twenty-six samples of blood and/or urine were received in connection with investigations into fatal traffic accidents. 135 of these consisted of "post-mortem" blood samples which were analysed for alcohol content as a routine procedure.

The distribution of the analytical figures for the various categories of persons involved in these accidents is shown in Table 8.

TABLE 8.

Alcohol per cent.	Drivers	Passengers (number involved)	Pedestrians
Negative	32	19	16
Less than 0·05	9	5	4
0·05–0·09	8	1	....
0·10–0·14	7	4	....
0·15–0·20	12	1	2
More than 0·20	10	3	2
	78	33	24

The above table indicates that 28 per cent. of fatally injured drivers had a blood alcohol figure of 0.15 per cent. or greater, while the corresponding figure for passengers and for pedestrians was 12 per cent. and 17 per cent. respectively.

These figures contrast with those for 1963 which were 45 per cent. in the case of drivers, and 17 per cent. and 23 per cent. respectively for passenger and pedestrians.

Voluntary Blood Alcohol Tests.

Two hundred and two samples of blood were submitted by the Police Department and 3 by Local Government Authorities in connection with charges of "driving while under the influence of intoxicating liquor." These samples were taken from persons who, on being charged with such offence, had exercised the right provided by the Traffic Act to have a blood sample taken by a doctor and submitted for chemical analysis.

The Traffic Act states that if the alcohol content of the blood at the time of the alleged offence is 0.15 per cent. or greater it shall be *prima facie* evidence that the accused was under the influence of intoxicating liquor at that time. The results of these analyses are set out in the following table, the figures being the alcohol content of the blood at the time of the alleged offence, calculated by the formula prescribed in the Blood Alcohol Test Regulations:—

Alcohol, per cent.	No. of Cases
Less than 0·15	16
0·15–0·20	57
0·21–0·25	80
0·26–0·30	42
More than 0·30	10
	205

From accused persons who pleaded not guilty, 93 samples of blood were sufficient in quantity to be analysed by two analysts, so that a total of 298 analyses were carried out in connection with this work.

Specimens from Patients.

There was a marked increase in the number of samples received under this classification. Approximately 80 specimens of blood and 70 of urine together with a small number of gastric washouts, hair and nails were analysed in connection with the medical examination of patients for clinical purposes as distinct from industrial hygiene and toxicology. The varying analyses performed under this classification are detailed in the following table:—

Type of analysis	Number
Amphetamine	58
Barbiturate	53
Copper	35
Lead	16
Arsenic	5
Kerosene	3
Mercury	3
Strychnine	2
Thallium	2
Alcohol	2
Boron	1
Chlorpromazine	1

Most of the samples of urine analysed for copper were for a hospital in connection with clinical investigations into the incidence of, and treatment of, Wilson's disease, in which high levels of copper excretion are observed.

Animal Toxicology.

Forty-five samples were received for examination in connection with 28 cases of suspected poisoning of animals. In 14 of these cases no poisonous substance was detected on analysis, while there were 5 cases where lead was detected in significant quantity, 3 of metaldehyde, 2 of arsenic and one each of mercury phosphorus and strychnine. In another case the symptoms and post mortem findings were consistent with the presence of nitrite detected in material consumed by the animals.

Investigations into Vitamin A deficiency were continued by the Animal Health Branch of the Department of Agriculture and six samples of animal liver were analysed for Vitamin A content.

Seven samples of suspected poison baits were received for analysis. Two of these contained strychnine.

Industrial Hygiene.

Three hundred and forty-nine samples were examined during the year in connection with industrial hygiene investigations, as compared with 233 in 1963.

One hundred and seventy-nine of these were specimens of urine from workers exposed to suspected lead hazard, and these were analysed in order to assist clinical diagnosis or as a process of "screening" to exclude the possibility of undue exposure.

Of these specimens, 123, or 68.7 per cent. contained less than 0.08 parts per million (milligram per litre) of lead (Pb). The range of figures recorded in these analyses is shown in the following table:—

LEAD (Pb)

Parts per million	Per cent. of samples
Less than 0·08	68·7
0·09–0·15	24·6
0·16–0·20	3·9
More than 0·20	2·8
	100·0

Other specimens of urine examined in connection with possible exposure to hazardous materials included 16 analyses for arsenic from pest control operators, 9 analyses for mercury from workers handling organic mercurial fungicides and one for arsenic and antimony from a worker using a bronzing powder which analysis had shown to contain both of these metals.

Eighteen samples of urine were analysed for phenol content and for ratio of inorganic to total sulphate in assessing the measure of exposure to benzene of persons working in a laboratory and a factory respectively.

One hundred and sixteen samples of air were analysed for various toxic substances. Seventy-nine of these samples were the result of inspection and testing of a wheat storage installation where fumigation with "Cyanogas" had been made and it was necessary to ensure that conditions were safe for further handling of the grain by workers.

Ten samples of air collected at different points and during different operations in assay offices were submitted for determination of lead content; while 5 samples analysed for T.D.L. (tolyl diisocyanate) were collected as a result of inspection during the manufacture of polyurethane printing rollers.

From a workshop engaged in testing diesel injectors a number of samples of air were analysed, first for oxygen content during the preliminary inspections, and then for kerosene content as a result of observations made during these inspections

Miscellaneous samples included tests to determine to what extent carbon monoxide from a motor vehicle exhaust pipe was drawn into the interior in varying conditions of speed and wind direction; analyses of dusts for "1080" during commercial manufacture of poisoned oats; analysis of urine of workers exposed to chlorinated hydrocarbons; and an inspection to ascertain the cause(s) of explosions which occurred while repairs on brine tanks were being carried out.

Pollution Surveys.

(1) Swan River.—Regular quarterly surveys of the Swan River were continued in 1964 when 145 samples of river water from normal sampling points were received and analysed for the Swan River Conservation Board.

Twenty-nine samples comprising trade effluents from specific factories or liquids flowing from various drains were also examined as a check on their suitability for discharge into the river.

(2) Leschenault Inlet Bunbury.—Examinations for the Public Works Department were continued in connection with the regular pollution surveys in summer and winter of the water in the Leschenault Inlet at Bunbury, and 48 samples were collected and analysed in the surveys in January and July, 1964.

(3) Maritime.—Six samples suspected of being oil were received and examined. These were alleged to have been discharged from ships into the waters of Fremantle Harbour, and were analysed in order to establish that they were in fact oil or material of similar nature.

Miscellaneous.

1. Waters.—124 samples were received under this classification from the Public Health Department.

Twenty-seven samples of water were submitted in an investigation to determine whether a known source of pollution was causing contamination of well waters through movement of underground streams.

An experiment extending over several months was undertaken by the Public Health Department to provide information on control of mosquito larvae in septic tanks systems, and in this connection 93 samples of water from septic tank soak wells were analysed, 88 for D.D.T. and 5 for malathion content. During these analyses it was noted that the D.D.T. was selectively adsorbed by the solid matter suspended in the soak well liquid, e.g. 0.4 parts per million of D.D.T. was detected in the clear liquid, and 20 parts per million of D.D.T. in the portion in which the solids were concentrated.

A sample of well water was analysed for phenolic substances because of its proximity to an industrial plant discharging "coal-tar type" effluent, while a check on an unusual chemical contamination of underground water, which commenced in 1960, showed that phenolic substances and chloro derivatives of phenoxyacetic acid were still present in the water.

2. Disinfectants. Experimental work was undertaken by the Public Health Department on a hypochlorite sterilising tank for more rapid and convenient disinfecting of limited items of hospital equipment. As it was necessary to maintain the "available" chlorine concentration at a figure of 200 parts per million, samples of liquid from the tank were analysed at intervals in order to provide information as to how this could best be achieved and maintained. In all 38 samples of disinfecting liquid were analysed for "available" chlorine content.

4. Pesticides.—175 samples of pesticides were received and examined during the year. Although less in number than the previous year, the variety of samples was equally extensive, as shown in the following table:—

Pesticide	No. of samples
Weedicides (2 : 4D type)	30
Aldrin (concentrate)	14
Aldrin (diluted emulsions)	34
Dieldrin (solid)	7
Dieldrin (concentrate)	14
Malathion (concentrate)	2
Malathion (diluted emulsions)	40
D.D.T. (concentrate)	3
Chlordane (concentrate)	3
Spraying oils	4
Commercial formulations	17
Vermin poison	4
Various	3

The 17 commercial formulations consisted of mixtures of insecticides which were analysed for the Pesticides Advisory Committee as a check on the composition of pesticides registered with the Public Health Department.

The samples of aldrin concentrate and diluted emulsions were examined for the Architectural Division, Public Works Department in connection with "white ant" preventive treatments applied to several building projects. Frequent sampling was carried out as a check on the quality of materials being used for treatment purposes.

Examinations for purposes of quality control were continued for the Weeds and Seeds Branch of the Department of Agriculture, and weedicides of the 2:4D type were analysed at regular intervals.

Malathion concentrates and diluted emulsions were analysed in connection with work on fruit fly control undertaken by the Horticulture Division of the Department of Agriculture. 32 samples of diluted emulsion were analysed to provide information on the "settling" of malathion emulsion during spraying operations.

Samples of technical dieldrin and of dieldrin and chlordane concentrates were analysed as a check on conformity to specifications required variously by the Agriculture Protection Board and in connection with work on Argentine Ant control.

5. Criminal.—There was a decrease in the number of exhibits received in connection with investigation of suspected crime.

Samples of charred debris from a house destroyed by fire were found to contain kerosene, and samples from a motor vehicle destroyed by fire were examined for an insurance company in an endeavour to trace the cause of the fire.

A variety of exhibits was examined in connection with a case of suspected abortion; and samples of cosmetics were analysed following allegations of malicious tampering. A foreign poisonous substance was detected in one sample of "make up" fluid.

Samples of wheat were analysed in an effort to provide information concerning thefts from bulk wheat depots; and patches of material adhering to the sole of a man's shoes were examined in detail to provide information which might assist in tracing his movements prior to his death.

6. General.—91 samples classified under detergents were received from the Government Tender Board. These varied from relatively simple synthetic detergents to composite soap powders, laundry adjuncts, liquid soap type cleaners with and without deodorant properties, steam-cleaning compounds and detergent type preparations for highly specialised uses. Extensive consideration was necessary in order to advise the Tender Board as to those which were most suitable for use in Government institutions.

Three samples of household soap and 5 samples of soap powder were analysed in detail for the Tender Board in order to assess their relative suitability for the purposes required by the Board.

The range of floor polishes for which tenders were called was greatly increased in 1965, with the result that a very considerable amount of work had to be carried out before recommendations could be made to the Tender Board as to which tender was considered most suitable for a specific item.

Considerable work was also carried out in investigations of suitable methods of analysis of "synthetic plastic" type paints submitted by the Tender Board.

Regular testing of "high altitude" oxygen for the Department of Air was continued throughout the year and 26 cylinders of oxygen were received and analysed for conformity with R.A.A.F. specifications.

Samples of sole leather and upper leather were received from a tannery at intervals and were analysed as a check on conformity with Commonwealth Government specifications.

Samples of poisoned oats were analysed for "1080" content in connection with tests of their deterioration when exposed to water which were being conducted by the Vermin Branch of the Agriculture Protection Board.

Fifteen samples of cotton seed and 22 samples of linseed were analysed for oil content, while an additional 56 samples of linseed were analysed for oil content and iodine value of the extracted oil.

A considerable increase occurred in the number of samples of building materials tested for "fire resistance". 43 Samples of widely varying types of materials were tested to assist the Public Health Department assess their suitability for use in public buildings.

Following reports of the occurrence of lead in imported plastic toys, 12 samples were submitted by the Public Health Department for examination. A very considerable amount of work was carried out as it was considered desirable to analyse the separate components of a toy where there were obvious differences in the colour or physical nature of the plastics, or where there was any adherent paint. In general it was found that significant quantities of lead occurred only in adherent "touches" of paint, chiefly in those of a yellow colour.

Because of publicity, samples of toothpaste contained in lead tube were examined to determine the concentration of lead in the paste itself and to assess the nature and effectiveness of the protective internal lining of the tube.

Forty-one phials of pethidine hydrochloride solution were assayed in connection with suspected tampering with drugs; two samples of atropine sulphate were analysed as a check on identity and concentration; chillblain cream was examined following complaints of adverse effects when used, and cachets of Sodium P.A.S. (sodium para amino salicylate) were assayed for conformity to specifications of the British Pharmacopoeia.

Samples of tallow, neatsfoot oil and sandalwood oil were analysed to determine their quality in terms of trade requirements, while a sample of carbide used underground in miners' lamps was examined for compliance with specifications.

Compressed air in cylinders for underwater swimming was analysed as a check on purity and on the "efficiency" of the air compressor, while samples of paint scrapings from a dredge being converted for water storage were examined to ensure the absence of lead in the paint.

A proprietary toilet cleaner submitted by the Public Health Department proved to be free from phenolic substances, but it was considered that too frequent use of the cleaner might be detrimental to the proper functioning of septic tank systems.

Miscellaneous samples received and examined during the year included a hand cleanser for determination of phenol content, fire retardant paints for testing for effectiveness, determination of traces of organic matter in inorganic explosives, a veterinary medicine for analysis for prohibited stimulant, wax-like materials found on the interior surface of a water conduit, a "drill core" for oil content, cattle and sheep dipping fluids, fuels for suspected contamination, and food dyes for examination and identification.

The normal inquiries for technical information and advice were received during the year, and expert evidence was tendered as required in various Courts by Messrs. Sedgman, Uren, Katnic, Double, McLinden, Mulder and Powell in connection with their official duties.

Building extensions to the Division were still in progress at the end of 1964 and it is still difficult to estimate when the extra accommodation will be available. At the administrative level this work has meant much extra time and effort in a field outside that of the chemist in order to appreciate and deal with the problems which have risen.

Although figures show that the overall volume of work is increasing sheer necessity has forced time to be devoted to analytical problems, particularly in the field of insecticides, and to a lesser extent of drugs. Towards the end of the year a gas chromatograph was put into operation, but the more urgent demands of specific problems have limited its use to date. Difficulties in the identification of unknown substances, particularly in the toxicological field, have become more noticeable with the expanding development and use of synthetic drugs, and call for increased acquaintance with and application of modern micro techniques and instrumental facilities.

FUEL TECHNOLOGY DIVISION.

There were 206 registrations of investigations and samples allocated to the Fuel Technology Division during the year 1964. They have related to analyses of coal and other fuels and gases, air pollution, light weight aggregates, the conductivity of insulating materials, dust arrestment, size analysis of dusts and to works investigations. They have ranged from an investigation of drying and firing conditions on a tunnel kiln making house bricks to the determination of the food calorie value of a dietetic soft drink. An investigation of considerable community interest has been into the sources, intensity and objectionable character of odours from the Subiaco Sewage Treatment Plant for which measures of alleviation were suggested and some of these have been implemented; as a consequence escape of odour from some stages of treatment has now been stopped and neighbourhood conditions should be improved. Demands of other work have permitted only one visit to Collie during the year to sample coal.

TABLE 9.

Fuel Technology Division.

——	Air Pollution Committee	Departmental	Geological Survey	Metropolitan Water Supply	Public Health Department	Other Government Departments	Main Roads Department	Hospitals	Public Pay	Total
Atmospheric pollution	19	41	....	13	18	3	....	4	....	98
Bricks and brickmaking	....	1	....	....	....	....	....	....	16	17
Building materials	....	....	....	....	....	....	....	....	7	7
Fuel—										
Coal	....	2	31	....	....	2	....	....	3	38
Oil	....	1	....	....	....	....	....	....	3	4
Other	....	1	....	....	....	....	....	....	11	12
Miscellaneous	....	15	1	....	....	4	4	....	6	30
	19	61	32	13	18	9	4	4	46	206

Coal and Other Fuels Analyses.

Relatively few coal and other fuel analyses have been made during the year. This reflects the restricted use of coal industrially and the reduction in mines worked at Collie. A sample of nut husk from Malaysia submitted by a boiler supplier for assessment as a boiler fuel indicates interest here and elsewhere in our work on fuels from waste. A series of residual fuel oil analyses shows an average of 3.4 per cent. of sulphur. It is useful to have these analyses as a running check on the sulphur content of fuel oil for air pollution assessment.

1. Collie Coal. (a) A sample was taken from the working face of the Hebe mine in the Muja area. The analysis is listed in Table 10 and shows no significant variation from previous analyses.

TABLE 10.

Average Analysis of Coal Samples from the Working Faces of Hebe Mine, Muja.

Proximate Analysis	Per cent.
Moisture	28·6
Ash	2·4
Volatile matter	27·7
Fixed carbon	41·3
	100·0
Calorific Value	Btu per pound
As mined	8980
Dry, ash-free	13010
Ash Fusion Point (reducing atmosphere)	°C. above 1260

TABLE 11.

Geological Survey Samples. Drilling Ahead of Muja Colliery.

Seam designation	Ate		Bellona			Ceres		Diana	Eos		Flora		Galatea	Hebe	
Hole number	S/10	S/6	S/10	S/6	S/4	S/10	S/6	S/10	S/10	S/4	S/10	S/4	S/10	S/10	S/4
Analysis—								Per cent.							
Moisture (a)	20·0	20·0	20·0	20·0	20·0	20·0	20·0	20·0	20·0	20·0	20·0	20·0	20·0	20·0	20·0
Ash	16·0	23·1	13·0	8·6	12·0	5·4	5·7	7·3	4·7	7·0	5·2	12·6	8·4	6·2	9·5
Volatile matter	25·4	24·5	26·5	28·3	25·6	29·9	29·7	28·9	30·6	28·3	27·6	23·5	25·0	27·8	26·2
Fixed carbon	38·6	32·4	40·5	43·1	42·4	44·7	44·6	43·8	44·7	44·7	47·2	43·9	46·6	46·0	44·3
	100·0	100·0	100·0	100·0	100·0	100·0	100·0	100·0	100·0	100·0	100·0	100·0	100·0	100·0	100·0
Calorific value—								Btu per pound							
20 per cent. moisture basis	8100	7260	8570	9140	8670	9670	9500	9420	9860	9460	9720	8550	8330	9580	9060
Dry. ash-free basis	12660	12760	12790	12800	12750	12960	12790	12960	13090	12960	13000	12690	13030	12980	12850

(a) This moisture content of 20 per cent. has been arbitrarily selected to provide a basis for comparison. The water content of coal in the seam will probably be in the range 25 to 31 per cent. by weight.

(b) The Director of the Geological Survey made available coal samples from drilling in the Muja area. The analyses are listed in Table 11 and the seam identifications are those of the Geological Survey. The ash content of some seams is relatively high, especially by comparison with the Hebe mine sample listed above in Table 10.

2. Wicherina.—Samples of drill cuttings from a bore to the south east of Wicherina were analysed. Approximately half of each sample was discarded because of its high specific gravity. The less dense coal material in each case was non-coking and high in ash content. The analyses are listed in Table 12.

TABLE 12.

Coal Drillings from Bore S.E. of Wicherina.

Lab. No.	3913	3914
Marks	2490′-2500′	2530′-2540′
	Per cent.	
Floats — Specific gravity below 1·58	47·3	57·1
Sinks—Specific gravity above 1·58	52·7	42·9

Proximate Analysis of Floats

	As analysed	Dry ash free	As analysed	Dry ash free
Moisture	11·8	....	11·5	....
Ash	15·3	....	17·6	....
Volatile matter	32·1	44·0	31·7	44·7
Fixed carbon	40·8	....	39·2	....
		Btu per lb.		
Calorific value	8910	12220	8,815	12430

Proximate Analysis of Sinks

		Per cent.		
Moisture	2·5	....	2·5	....
Ash	78·5	....	78·9	....

These coals did not coke.

3. Other Solid Fuel.—Samples of fibre and nuts from trees indigenous to Malaya were received on behalf of a local engineering firm. The analyses are listed in Table 13.

TABLE 13.

Malaysian Nut Residue Fuel.

Lab. No.	6536–41	6542	....
Sample	Fibre	Kernels	Mixed fibre and nut
		Per cent.	
Moisture	36·0	19·6	16·0 (*a*)
Ash	3·9	2·2	3·6
Calorific value—		Btu per pound	
As analysed	5680	7180	7480
Dry, ash-free	9450	9180	9300

(*a*) This sample had been air-dried in the laboratory. Jarrah wood has a calorific value of 8800 Btu per pound of dry wood.

Oil.

Three samples of fuel oil were received. The average calorific value was 18550 Btu per pound and the average sulphur content was 3.4 per cent.

Natural Gas.

1. Kalgoorlie.—Gas recovered from a drill hole proved to be 88 per cent. methane. Such occurrences are not rare and the gas is suspected to be of sedimentary origin.

2. Wyndham.—Gas encountered in oil drilling in this area contained 83.9 per cent. methane and 14.1 per cent. higher hydrocarbon gases.

Soft Drinks.

A less usual fuel submitted for calorific value determination was a low calorie soft drink. It returned a value of 0.74 kilo-calories per fluid ounce equivalent to 5.9 kilo-calories per 8 fluid ounce bottle. Kilo-calorie is the scientific name for the CALORIE of dietetics.

(It is an interesting matter to present the CALORIE intake of the human body, 2,500-3,000 CALORIES per day (10,000-12,000 Btu) in terms of the petrol consumption of an internal combustion engine. Petrol has a calorific value of 18,000 Btu per pound. Thus the human body uses for a day's work and movement less heat energy than would serve even a small petrol driven vehicle to travel 5 or 10 miles. Such a distance travelled on foot would by no means exhaust the average adult.)

Applied Fuel Technology.

Work has been done on plant and boilers and on domestic appliances. Major items have been a hospital laundry steam survey and an examination of solar water heating on which we have had an informative exchange of opinions with C.S.I.R.O. Division of Mechanical Engineering.

1. Boiler and Laundry Survey.—The Division was consulted in relation to the capacity of boilers for the proposed extension of buildings and services of a hospital. The services included a laundry which, like all laundries, drew a fluctuating load related to the heavy draws when washing machines are filled and boiled. The situation thus presented is of major seasonal fluctuation associated with the institution heating load in winter, plus the major fluctuation brought about by the operation of the laundry in the day time only, plus the incidental fluctuation introduced by washing machines.

The solution proposed comprised improvements in hot water storage for the washing machines which would reduce the incidence of their demands on peak loads in major degree; additionally it was suggested that the laundry have its own boiler which was started up only during the laundry working periods.

The advantages of retaining wood fired boilers were emphasised. It is claimed by operators that these are cheaper to operate and to service than high capacity oil fired boilers. They solve the problem of incineration of waste and do not rely on an imported fuel. Wood supplies for boiler fuel are, according to forestry reports, inexhaustible in the foreseeable future. Wood presents neither the bunkerage nor ash removal problems associated with coal as a fuel.

The hospital demands were finally set out as follows:—

	Average	Peak
	Lb. steam f & a 212° F. per hour	
General (excepting laundry)	4,800	5,900
Laundry (unimproved)	3,200	4,000
Laundry (improved relative to water storage)	2,900	3,400

2. Solid Fuel Domestic Water Heaters.—There is considerable interest in the solid-fuel fired storage water heater at the present time. The State Housing Commission is installing them now in many of their houses and there is a general realisation of their merits and of their low cost of operation amongst householders. This may in part owe to the analysis of costs made by us some years back when publishing on costs of water heating for domestic supply. There are now a number of models on the market mainly of all copper type. An alternative design was tested which consisted essentially of a hot water cylindrical tank with a central axial flue which carried off the combustion products from the fire burning in a firebox under the hot water cylinder. The firebox was lined with refractory brick. It was claimed for this that because of the brick lining the fire would burn fuel and especially rubbish more effectively. By performance tests it was found that the combustion behaviour was not demonstrably better than heaters with copper fireboxes while the rate of water heating and thermal efficiency were less. Copper fireboxes give 40 per cent. efficiency while the brick lined fireboxes show rather less than 30 per cent., rated on Btu's put in as fuel to Btu's recovered as hot water.

A firm originating heaters with refractory lined fireboxes has now produced a copper firebox model which has shown the expected efficiency of 40 per cent. when tested. It is noted however that others who have manufactured only copper firebox type water heaters in the past are now marketing a type with a refractory lining.

In the course of this work thought has inevitably been turned to designs and a suggested arrangement (Fig. 6) which appears to have the merit of low cost manufacture and efficiency in performance has been evolved.

3. Solar Water Heating.—Solar water heating is frequently advocated for domestic hot water supply. The Mechanical Engineering Division of C.S.I.R.O. has carried out work which has fostered it. Enquiries are received from time to time on its merits and economics. Probable performances of solar heaters in the latitude of Perth have

therefore been examined by a method of calculation which gives results similar to those advanced by C.S.I.R.O.

The conclusion reached was that solar water heating is high in capital cost as compared with solid fuel or oil fired heaters. Solar heating is also by no means an all the year round, day by day satisfactory way of water heating without the addition of electrical boosting In overall capital and running costs solar heating will normally be considerably cheaper than electrical or gas heating of water. It appears to break even with oil heated hot water storage systems. It is much higher in both capital and running costs than solid fuel hot water storage heaters where wood supply is as cheap and adequate as it commonly is in most parts of the State.

In the course of the work the expected performance of solar water heaters for each month of the year at latitude 32°S was calculated and then expressed in terms of hot water heated from 60°F to 140°F by a 24 sq. ft. absorber, a size popular in this State. These are set out in Table 14 where it is seen that the performance is good from October to March but falls off badly in the winter months. At all times of year there are some bad minimum days when little hot water is collected or when heat may actually be lost from the system.

Calculation from results suggests that on the basis of 40 gallons of water heated from 60°F to 140°F as a day's supply for an average household the cost of boosting the hot water from the solar system by electrical heating is at £15 3s. per annum almost exactly the hot water supply provided completely by oil fuel for which a general figure of 10d. per day is advanced giving £15 4s. per annum. The capital cost of an oil fired system is probably rather less than half that of a solar heated system.

The basis of these figures was agreed with C.S.I.R.O. Mechanical Engineering Division to within reasonable concordance for data which depend on a number of factors of uncertain value.

TABLE 14.

Solar Water Heater Performance.

Month	Gallons per day of hot water at 140° F. from 24 sq. ft. absorber: Absolute maximum	Average	Absolute minimum
January	50·4	37·8	2·7
February	56·1	41·8	....
March	51·6	30·3	....
April	38·8	16·8	....
May	31·6	10·0	....
June	27·4	6·4	....
July	16·5	10·0	....
August	24·4	10·6	....
September	32·7	17·6	....
October	35·3	25·7	2·3
November	45·7	31·4	6·7
December	56·6	34·0	6·8

	C.S.I.R.O. values	Our values
Average absorption of heat (Btu per sq. ft. per day)	1880	1660
Per cent. of heat producing hot water	40	39

4.—Heating of Swimming Baths.—An opinion was requested by a Shire Council on the heating demand of a swimming, diving and learners' and paddling pools of a total surface area of 10,000 square feet. The demand varies with the time of year and the wind velocity. Wind velocities average about 8 knots in the State but pools are normally somewhat protected from wind. Heat losses were therefore calculated for a 5 knot wind. Winter and summer figures obtained were as follows:

	Btu per 10,000 sq. ft. per hour to maintain 70° F.
Winter	1,000,000
Summer	200,000
Spring	900,000
Autumn	300,000

The sun will have a marked modifying effect on the demand as in summer the solar energy falling on 10,000 sq. ft. averages 1,000,000 Btu per hour, and in winter 330,000 Btu per hour over the twenty four hours. From these figures it would appear that conditions in swimming baths could be kept quite comfortably warm if they are protected from the prevailing South and South West winds and are open to receive maximum insolation from the North. If they were additionally protected from night chilling and evaporation by plastic covers either very little addition or possibly no addition at all of artificial heat would be required.

The increase in numbers of major public swimming pools merits consideration of the need and methods for heating them as heating plant and fuel can be major items in the expenditure on pools. It is also possible that those who would wish to use them throughout the year may be small in numbers and of such hardihood that they would not be disturbed by low winter temperatures in unheated pools.

Air Pollution.

Investigation of a number of sources of local air pollution and general survey work on dust deposition at various points in the Metropolitan Area have occupied much time in the past year.

1. Sewage Odour.—One investigation of considerable interest has been that of the sources of odour fom the Subiaco Sewage Treatment Works. The process operated at Subiaco is one of preaeration followed by separation of sludge from liquid sewage. The latter is then aerated in contact with recirculated active sludge. The sludge separated in the first stage of treatment is thickened and then digested by anaerobic fermentation to produce methane mixed with carbon dioxide. The gas given off is used for power generation and air compression and any surplus is burnt. The digested sludge is discharged to drying beds.

Opinions differ as to the importance of the odours from various sections of the plant, but general consensus of opinion is that one of the worst, if not the worst, is from the sludge thickening stage where previously separated sludge was air blown in open tanks. The odour produced is a rank mercaptan odour which, in suitable weather conditions, is detectable and at times objectionable at distances up to one mile from the source. The covering of these sludge thickening tanks was recommended. This has been done and the foul air generated in them is now drawn off and burnt with digester gas and this destroys the odour effectively and simply. Improved designs of foul air burners are now being considered as an equally simple and economical way of removing odour from air vented elsewhere in sewage transport and treatment.

Other stages of treatment of the sewage give odours but not so offensive in character as that from the sludge thickeners. The present recommended policy is to assess the reduction in nuisance achieved by the present measures and from the results and experience decide what, if any, further steps have to be taken.

One useful and valuable piece of information obtained in the course of investigations is that hydrogen sulphide is destroyed by air blowing septic sewage, and this may prove helpful in destroying hydrogen sulphide in sewage in transit. This would give sweeter sewage into the treatment plant and should as well reduce or stop completely corrosion of concrete sewage pipes by sulphuric acid formed by oxidation.

In the course of the investigation some understanding has been obtained of the movements of odours in light winds. In such winds of about 5 knots strength, smoke and pollution do not spread but apparently move away from the source in a relatively narrow cone. If there is as well an inversion condition there is no marked rise of the plume or stream of odour and it can therefore be carried in detectable strength for considerable distances. The sewage odour can be carried for at least one mile. Somewhat similar odours said to come from Kwinana can be detected in Perth. In both instances the odours have been released close to ground level. The use of higher vent points, in all probability, would prevent the odour reaching ground level and creating a nuisance. A study of the relation of height of release of smoke and gases to their detection at ground level is of importance in deciding upon chimney heights suited to larger industrial undertakings to the prevailing windward of the Metropolitan Area.

2. Alumina Refinery Emissions.—The ALCOA alumina refinery at South Coogee has created some local nuisance during its starting up period. There is some sulphur dioxide emission from the boiler chimneys which are too short for the amount of oil burnt in respect of their situation to the prevailing windward of nearby high ground developed to some extent as residential sites. There is also a characteristic caustic soda odour which is detectable from positions within about half a mile of the works. This odour is slight and clean in character and should not be a cause of complaint. There have been some apparently heavy emissions of dust when trouble has developed on the calcining kiln. The source of trouble has been the operation of a conveyor removing product from the dust arrestment plant. It is possible as well that product is being emitted as dust because of condensation and corrosion troubles associated with the use of fuel oil of high sulphur content for firing the kiln. A method of arresting this would be to use producer gas made from Collie coal for firing the kilns.

Our contacts have not been close with any of the difficulties encountered at the refinery so that it has not been easy to implement any improvements which have suggested themselves. It is understood however that the boiler chimneys are to be raised to a more adequate height to reduce local sulphur dioxide pollution.

3. Institutional Incinerators—Princess Margaret Hospital incinerator has been a cause of nuisance in burning paper and other hospital refuse. Some smoke is emitted and at times charred paper fragments. The main trouble occurs when the incinerator is opened for charging. The increased through draft causes charred paper and ash to be carried out of the chimney. After charging, smoke increases for a short time. When the door is closed and the fire is undisturbed the incinerator does not cause nuisance. A remedy might lie in using a lock type hopper to charge without letting excessive draft go through the door. The measures recommended however are to fit a cyclone and exhaust fan on the incinerator so that it operates on induced draft with dust arrestment in its more active periods. This appears to be the most positive way of dealing with the situation. Aerodynamic cones can also be considered and it has been suggested that water tray devices may be used which will hold paper and ash so that they cannot be re-entrained during periods of excessive draft.

Institutional incinerators present a special problem in air pollution when they operate on natural draft as they normally do. Unfortunately advice is often asked on prevention of pollution after the incinerator has gone to work. It would be easier to incorporate remedies before the incinerator is built than after.

4. Fluoride from Brickworks.—Measurements of hydrogen fluoride emission from a brickworks kiln were made for Cardup-Metropolitan Brickworks on new tunnel kilns. The average emission was 100 ppm. of fluorine as fluoride in the chimney gases. It was calculated that this would give 0.45 ppm. of fluorine at ground level. Additionally the sulphur dioxide in stack gases at ground level would total 0.75 ppm. Both these quantities are a little higher than limits normally accepted. The recommendation made was that conditions of neighbouring vegetation should be observed and tested over a period of a year to find out if the average conditions were now acceptable. If not, the chimney, which had been raised from an original roof level to 40 feet above ground, should be increased a further 20 feet.

5. Kwinana Industrial Area.—The increasing emission of sulphur oxides from industrial development in the Kwinana Area has engaged attention. Residual fuel oil of 2.5-3.5 sulphur content appears to be used exclusively in the new works and factories. Each new major industry may use of the order of one hundred tons of oil fuel per day with an accompanying sulphur oxide emission of 5.0 to 7.0 tons per 100 tons of oil. Little thought appears to have been given to the dissipation of these amounts of sulphur oxide pollution.

In brisk winds, with high atmospheric temperature lapse rates it can be hoped that the pollution will not obtrude at ground level in objectionable concentrations. It may however cause high level haze.

As the axis of the Kwinana development is along a South-North line, light southerly winds must become considerably charged with pollution as they travel over the succession of new works along this axis. If, as well, an inversion condition prevails it is possible that a belt of polluted air may then extend from Kwinana to Fremantle and the Western suburbs of Perth. It is possible for such a plume to cause considerable ground level pollution especially during the break up period of the inversion.

These possibilities should be kept in mind in the siting and planning of additions to the Kwinana development and especial attention should be given to adequate chimney heights.

6. Foundry Cupola Dust.—At the commencement of the year deposit gauges were placed on the normal leeward side of Metters foundry cupola at Subiaco at points near to where complainants had reported foundry dust deposition characterised by iron particles which left rust marks. Over the periods of the tests made a water type grit arrestor was in operation on the cupola. It consists of a large cone over which a considerable volume of water flows to give a dense curtain of water through which the cupola gases have to flow. Whenever it was in operation dust and grit were not detectable within the area of fall from the cupola. At times the water flow became blocked and heavy grit falls were immediately noticeable on surfaces close to the cupola such as a sheet of ply or the upper surfaces of a parked car. This seemed to provide the best way of assessing the efficiency of the arrestor.

The deposit gauges did not collect excessive amounts of dust. The quantities ranged from a collection rate equivalent to 60 tons per square mile per annum to 120 tons on the same basis. The dust constituents were mainly fine surface sand but there were some iron oxide, coke particles and calcite visible under the microscope.

7. Titanium Oxide Works.—The starting up of the new Laporte Titanium Oxide Works at Australind gave rise to complaints from nearby residents living only about a chain to the North of the works. The works was visited and the conclusion was reached that no odour or nuisance could come from the main chimneys of the works which are carried up to an adequate height and are additionally jetted to give their plumes extra rise. There was, nevertheless, a slight odour of hydrogen sulphide in the neighbourhood of the digesters and some nuisance could result from low level chimney discharge of the oil fired boilers used as auxiliaries to supplement the main waste heater boiler supply of the works.

A suggestion was made that the height of a gas vent could be increased to 50 ft. on the digesters and that the boiler stacks should be raised well above tree top level. This would have corrected air pollution nuisance adequately.

Dust Deposition.

Study of the dust deposit pattern round the Metropolitan Area has been continued this year. Two gauges have been kept in the industrial areas of East Perth and Rivervale. Three new ones have been set up in residential sites at Wembley, Swanbourne and Redcliffe. The deposit figures from these are low and show that the general level of dust pollution over Perth is low and is mainly surface sand and other dust and organic matter.

TABLE 15.

Dust Deposition 1964, Metropolitan Area.

Test Position	Summer Max.	Summer Av.	Summer Min.	Winter Max.	Winter Av.	Winter Min.
	Rate of deposition (Tons per square mile per year)					
Industrial—						
East Perth	370	280	160	210	180	160
Rivervale	140	120	70	150	130	80
Residential—						
Redcliffe	80	50	30	....	20	....
Wembley	70	50	40	60	30	15
Swanbourne	80	40	20	....	....	....

The average loss on ignition of samples is about 50 per cent. indicating considerable organic matter. The major inorganic constituent is always silica, a little limonite and usually coke or carbon of some kind is present in small amounts. The two industrial sites also show a few cenospheres which will have originated either from the Power Station at East Perth or from locomotives.

The conclusion is that Perth has no general dust or soot problem.

Dust Arrestment and Size analysis.

The work on the dust settlement apparatus train located at the Engineering Chemistry Division at Bentley proceeds intermittently but satisfactorily. Three types of separator have been tested. One is a louvre settlement type which does not show high efficiences and would be of doubtful industrial value. The other two are aerodynamic cone types which show over 75 per cent. efficiency in application to a number of industrial dusts. They appear to have scope as removers, with low pressure loss, of the major part of dust burdens in gases, down to contents which may in some cases be acceptable for emission or in others for treatment in high efficiency dust removal units whose operation is assisted by the previous removal of the bulk of the dust, particularly the coarser fractions. The presence of coarse dust frequently disturbs the operation of units designed to remove fine dust and, in any event, performance in dust removal is normally developed as characteristic fractions of the inlet dust burden so that the lower this is the lower the final emission.

The suitability of aerodynamic separators for use on incinerators merits study. The problem here is to design a separator which has a low pressure loss and is still reasonably efficient. There is also a variation in available draft between incinerators on flats and those with low chimneys at hospitals.

Size Analysis—Samples of agricultural limestone, zinc oxide, silty clay, iron oxide, gypsum, "red mud," and a standard finely ground silica flour have been subjected to sub-sieve size analysis using either the EEL photosedimentometer or the ROLLER air elutriation apparatus.

The silica flour used is a standard material available from an English company and commonly used as a reference standard in size analysis and dust separation. One purpose for obtaining it was testing in the dust settlement train. The other is to establish a reference material for intercomparison with other laboratories doing sub-sieve size analysis work. It proves cheaper to import this fine sand than to attempt to prepare it ourselves from indigenous material.

On samples sent for our guidance in selection of a suitable bulk delivery the following size analyses were obtained using both EEL photosedimentometer and the Roller Elutriator. The agreement is reasonable for two methods so widely different in principle and medium for separation.

TABLE 16.

Size Analyses of Silica Sands.

Sample	M-2		M-3		M-7C		MSC
Lab. No. (1964)	3279		3280		3281		8359
	Eel	Roller	Eel	Roller	Eel	Roller	Eel
Size (micron)	Per cent.		Per cent.		Per cent.		Per cent.
0– 5	9	8	12	12	9	10	69
5–10	16	18	15	19	9	9	26
10–20	24	26	28	25	15	13	10
20–30	17	7	21	17	13	10	....
30–53	28	35	20	23	21	25	....
+ 53	6	6	4	4	33	33	....

On the basis of the above examination a bulk delivery of the M-2 material was ordered which gave the following size analysis:

TABLE 17.

Size Analysis by Photosedimentometer of M-2 Sand, Bulk Delivery.

Size (microns)	Percent
0– 1	1·4
1– 2	1·2
2– 6	13·2
6–10	13·3
10–15	25·5
15–20	11·6
20–30	15·6
30–45	18·2

These plotted give a smooth distribution of a shape which shows that the sand is well suited for test purposes.

Bricks and Refractories.

A number of clays have been examined for their refractory behaviour. A standard apparatus has been acquired for refractoriness under load examination. An oil fired furnace has also been equipped for the examination of whole brick samples.

We were also asked to investigate failures of housebricks in drying and firing operations on a new tunnel kiln installation. The investigation was an extensive one and occupied staff for considerable periods over the course of about two months. Causes of the failures were found and suggestions made for eliminating them.

The use of tunnel kilns for housebricks is a recent innovation in the brick industry in this State. Two sources of trouble are encountered. One is slump of the bricks through exposure to high humidities in drying. The cause seems to lie in increase of plasticity with rise of temperature in conditions where humidity is so high that bricks do not dry as their temperature increases. With increasing plasticity bricks become susceptible to shear failure and thus split and collapse. Those bricks at the bottom of stacks on cars in kilns are under the highest loads and so collapse first and then cause collapse of the whole car load. The use of what is termed "high humidity drying" in tunnel kilns must therefore be exercised with caution. Where bricks do not shrink excessively or crack in drying, humidities are possibly most advantageously kept at low levels.

The second type of failure is associated with shrinkage or expansion in drying and firing. If bricks shrink on drying or expand on firing any major difference in conditions between the inside and the outside of stacks of bricks on cars may cause more shrinkage or expansion on the one side as compared with the other. This may be sufficient to cause the development of tilts in the stacks of bricks which will impose shearing moments on some of the bricks in the stacks and crack them. Evidence that this can happen has been provided from the drying shrinkages of bricks and by their expansions in heating up as examined in the laboratory.

In support of the foregoing views it is found on the kiln that bricks which shrink 2.0 per cent. in drying developed a considerable proportion of fractured bricks whereas bricks which do not shrink in drying developed no fractures.

In firing it was found that bricks which developed strength in the early stages of firing, up to 900°C, were not fractured on emergence from the kiln whereas those which did not develop strength showed an unacceptably high percentage of spoiled bricks. With both kinds of bricks the expansion on heating curves were similar, as shown in Fig. 7, but the development of strength was different. Thus it appears that although the strains imposed on the bricks in stacks are similar the resistance to stress is the factor which affects the development of cracks in bricks in the kiln.

This suggestion was borne out by the inspection of a kiln which had been stopped and cooled down full of bricks during a holiday period. The development of cracks in the bricks coincided with 600-800°C heating zone of the kiln which corresponds with the development of the maximum rate of expansion in the heating curves of the bricks themselves.

This observation is of both importance and interest in the operation of tunnel kilns as it is commonly stated that cracking occurs round 600°C in cooling bricks because of the sudden contraction of silica at 575°C. The heating and cooling curves of Fig. 7 suggest strongly that expansion on heating rather than contraction on cooling can be the behaviour of greater significance in the development of strength in bricks.

TABLE 18.

Crushing Strength of Brick Making Mixtures at Increasing Temperatures.

Temperature (° C.)	Crushing strength, psi Red	Pastel
400	390	720
500	500	830
600	390	1,000
700	600	1,280
800	720	1,780
900	1,000	1,780
1,000	1,280	2,000

Thermal Conductivity.

Thermal conductivity determinations using our axial flow, cylindrical test piece method have been made on insulating and on standard concrete samples. The method has also proved of great value in application to expanded plastics now extensively used for insulation of refrigerators and cold storage. Conductivities of such materials are difficult to determine by other methods. The axial flow method has proved rapid and reliable and enables measurements of conductivity to be made over a considerable temperature range quite quickly although with attainment of equilibrium conditions at each temperature. Attainment of equilibrium is almost impossible using other methods for materials of low thermal conductivity.

TABLE 19.

Thermal Conductivities.

Substance	Thermal conductivity Cal. per sq. cm. sec. deg. C. per cm. thickness	Btu per sq. ft. h deg. F. per inch thickness	Temperature ° C.
Insulating Brick	$0 \cdot 65 \times 10^{-3}$	$1 \cdot 922$	500
Insulating Concrete....	$0 \cdot 8 \times 10^{-3}$ $\times 10^{-5}$	$2 \cdot 355$ $\times 10^{-2}$	450
Polyurethane (Sp. Gr. 0·036)	5·5–6·5	1·6–1·9	40–120
Polyurethane (Sp. Gr. 0·029)	6·1–7·0	1·8–2·0	50–110
Polystyrene (Sp. Gr. 0·03)	7·0–8·4	2·0–2·4	30– 90
Polystyrene Pellets	7·3–9·1	2·3–2·6	18– 85
Onazote (Sp. Gr. 0·076)	7·6–8·7	2·2–2·6	45–110
Balsa Wood (Sp. Gr. 0·158)	8·2–8·8	2·4–2·6	43–125

General.

Committees.—Committee work has been done on an Air Pollution Advisory Committee of the Public Health Department and on an *ad hoc* sub-committee of the Metropolitan Water Supply and Sewerage Board concerned to stop escape of odour from sewage processing at its Subiaco Treatment Plant. Nomination to a newly formed National Coal Research Advisory Committee has been accepted and one of its meetings has been attended in Sydney. At the request of the Public Health Department a National Air Pollution Conference was attended in Melbourne.

Papers Read or Published.—A paper on Air Pollution in Western Australia was read to the State Group of the Institute of Fuel. A paper has been prepared for presentation to a National Conference of the Chemical Engineering Branch of the Institution of Engineers, Australia in Sydney. The basis of the paper is a presentation of the Chemical Engineering contributions of the Laboratories over the past fifteen years. In sum they are not inconsiderable.

INDUSTRIAL CHEMISTRY DIVISION.

General.

Staff.

The staff at 31st December, 1964, comprised five chemists (including the Divisional Chief), a laboratory technician and two laboratory assistants.

Mr. A. Reid was at Warburton, Victoria, for the Oil and Colour Chemists Association annual meeting in July and in Melbourne for the Plastics Institute of Australia Convention which followed. Both conferences were extremely successful and a great deal of useful information was acquired, apart from the firming of earlier professional friendships and the forming of new. An interesting point was that Western Australia's reinforced plastics industry, although lacking in modern equipment, need fear nothing as far as quality and workmanship are concerned.

Mr. Reid continued to lecture on reinforced plastics in the evening at Carlisle Technical School. The course has now been expanded to a 3-year one and is recognised in the U.S.A., U.K. and the Continent whilst the syllabus is proposed as the basis for similar courses in other parts of Australia.

Classification of Work.—As in previous years the work may be classified as:—

- Routine
- Consultative Practice
- Developmental Research (including investigational).

These categories are not mutually exclusive. Consultative practice may also be taken to include some types of investigational work.

TABLE 20.

Industrial Chemistry Division.

——	Agriculture Department	Departmental	Industrial Development Department	Public Works Department	Other Government Departments	Public Pay	Total
Building materials	....	....	....	6	7	14	27
Furnishings	....	....	6	9	....	....	15
Plastics	5	2	....	3	....	2	12
Tiles	....	....	....	5	....	1	6
Miscellaneous	2	4	....	....	5	10	21
	7	6	6	23	12	27	81

Routine Work.

In all, 65 samples came under this classification, covering a wide range of materials.

In contrast to previous years no cement additives were examined but two samples of set-concrete were analysed to find if cement additives had been included in the mix.

Two samples of sandalwood were steam distilled for oil content. One was found to contain less than 0.1 per cent. of steam volatile oil.

The water vapour transfer of two plastic bags was determined to decide on the type of bag to be used for packaging poison baits.

Solvent resistance of two samples of foamed polystyrene was determined and methods of precoating to improve the resistance were experimentally determined.

Six samples of anodised aluminium were examined as to the quality of the anodizing.

The ash content of two P.V.C. waterstops was determined to help decide on selection of a suitable type for a specific job.

Reports were prepared on a number of samples of paint and metals such as aluminium and galvanised iron which had been on exposure at our marine exposure station at Woodman's Point. Results varied from satisfactory to very poor. Some exposures were as long as two years.

The action of ultra-violet light on painted metal strips submitted by the Main Roads Department proved interesting; over the exposure period none was completely unaffected.

For the Department of Industrial Development four samples of enamelled steel hand basins were examined for acid, alkali and abrasion resistance.

Amongst miscellaneous other samples were paints, plastics (for identification), crackel, timber, faulty vinyl tiles, slate powder, hot-mix asphalt and steel shelving.

Consultation Work.—Advisory Service.

There was no lack of variety in queries addressed to the Division. Quite a number had a confidential or semi-confidential basis and cannot, therefore, be discussed in this report.

Questions on paints, plastics and building materials continued to dominate but there were also interesting enquiries from completely unrelated fields. Some examples of the types of enquiries follow.

A number of plastics were identified for potential users and advice given on their properties and uses.

A case of failure of a section of reinforced plastics corrugated sheeting was explained as being due to the omission of a surface tissue glass layer and to the use of a polyester not modified against weathering effects.

A plaster board manufacturer, troubled by mould growth on his plaster sheets, found the growth immune to normal inhibitors. He was advised of other methods which made possible both prevention of staining in new sheets and the reclamation of sheets already stained.

Among the many paint systems suggested to various clients was one for the Forests Department to be used on Native Flora Protection signs.

Iron stains on walls caused by bore water were a common source of enquiry. Remedial measures were suggested with a moderate degree of success.

Protection of steel and other metals against corrosive atmospheres and liquids, especially in factories, was discussed with a number of clients, mostly engineers, and architects. A number of manufacturers are now replacing units conventionally erected in steel by units in plastics such as polyethylene, polypropylene, A.B.S., acetal, and P.V.C.

A number of problems in connection with the strength requirements, especially of reinforced plastics structures, were answered for enquirers.

More and more enquiries come to hand on sources of raw materials, specifications, standards, and on agencies for manufacturers of specified goods. With the very valuable help of other orgaisations, such as the State Library, and individuals, over 80 per cent. of all enquiries were answered. In order to maintain this service a system of cooperation between this Division, a number of specialists and organisations now exists and functions smoothly. Products, the origin of which were traced, included some which were manufactured in the U.S.A., U.K., West Germany, Japan, the Netherlands, France and Formosa; in many cases the name of Australian, and where present, Western Australian agents were advised.

The Advisory Service continues to play its small part in the technological life of the community.

Investigational.

(1) Spray vs. Drum Drying.—In order to obtain design and performance drying of a product a number of experimental test runs were made on behalf of a local manufacturer.

Prior to the experimental work the manufacturer had been diluting the viscous solution and drying it successfully, but uneconomically, in a spray drier.

Using the Division's pilot plant film (drum) drier a product of suitable physical condition was obtained without the necessity for dilution of the original viscous solution.

From the expermental data obtained the client was in a position to design or purchase a drier to his exact requirements. Nine samples were worked on in the course of this work.

(2) Spray-Drying of Iron Oxide Slurry.—Iron oxide slurry, a product of ilmenite upgrading was successfully dried in the Pilot Plant spray drier without agglomeration of particles. This work was done for the Engineering Chemistry Division.

(3) Vinyl Tiles.—The number of types of vinyl tile available on the local market continues to grow steadily. In writing a specification the average architect is finding it more and more dfficult to specify the kind of tile he wants and the properties it should have and as a result he has to study a considerable number of tenders with no assurance that he is getting what he wants. Broadly speaking he has a choice between rigid and flexible tiles; no satisfactory definition of the term "flexible tile" seems to be forthcoming, although there are standards and proposed standards for them.

It seemed that by examining some of the physical properties of the tiles such as abrasion and scratch resistance, indentation recovery and "stiffness" value (as used in the A.S.T.M.) these might be correlated with for example resin/plasticizer concentration. On that basis it might be possible to classify flexible tiles into rough groups of reasonably well-defined properties and architects might eventually be able to specify a group of tiles as meeting his considered requirements.

With the full co-operation of all tile manufacturers and agents a considerable amount of work has been done on these lines and a draft report is presently under consideration.

Abrasion resistance was found to show a strong positive correlation with plastic concentration and scratch resistance seemed to offer a positive correlation. Indentation recovery was greatest in tiles of high plastic content.

"Stiffness" value appeared reduced as the plastic concentration increased but some doubt may be expressed as to the definition of this term and the method of determining it (we used a simple bending apparatus on which the modulus of elacticity was estimated).

A satisfactory definition of "foot-comfort value" is naturally one which would excite controversy. In the draft report this property has been considered in relation to tile thickness and "stiffness".

It was suggested in the draft report that if the resistance to abrasion and scratching were an indication of tile durability, measurements of "stiffness" value might possibly be a useful parameter in determining durability and foot-comfort.

Further investigations are necessary and correlation with actual wear of tiles in use is required. Attention is also being paid to reports of measurements of foot comfort by medical men using specially designed equipment.

Four new samples of tiles were examined in the course of this work together with fourteen registered in 1962 and a further ten in 1963.

Developmental Research.

Reduction in the number of routine analyses and testing, mentioned earlier, made possible an increase in developmental research work.

(1) Measurement and evaluation of "Slip".—Work on this project has produced convincing evidence that slipperiness of a surface cannot be assessed either by a layman or a scientist unfamiliar with the factors involved; it certainly cannot be assessed by visual or tactile methods or by the use of any apparatus which does not take into account the many variables in the mechanism of slipping, and those of the associated action of walking.

To this end numerous experiments have been carried out in order to establish the suitability of both method and apparatus. Thus walkways and other surfaces can now be classified in order of slipperiness. Either the acceleration figure or the coefficient of kinetic friction can be used in this evaluation, and this figure can be further compared with standard surfaces or with a theoretically smooth surface. It is also possible to assess a surface for its degree of safety as a walkway because the forces determined by the use of the apparatus can be evaluated against the horizontal force exerted during the process of walking, as determined by workers in the U.K. and U.S.A.

The designing of a portable apparatus meeting the above criteria is nearing completion; portable apparatus will enable tests to be carried out on surfaces already in place.

(2) Preparation of Lithium salts from Petalite and Lepidolite.—An investigation is being carried out into methods of obtaining lithium salts from these two minerals. Various methods of decomposing the minerals are being tried with some success, and future work will comprise (a) establishing optimum conditions for decomposition, e.g., times and temperatures of roasting and (b) methods of separating the soluble lithium from other materials extracted.

In the case of petalite, experiments have been carried out initially to find means of decomposing the ore and, subsequently, to separate lithium from other elements in solution.

It was found that petalite is more amenable to decomposition techniques after conversion to β-spodumene. After this, fusion with sodium chloride at 900-1000°C released lithium as lithium chloride which could be leached out quite easily together with other soluble salts.

Preliminary experiments indicate that lithium can be separated from the other elements in solution by the use of ion-exchange methods. A considerable amount of work has still to be done to determine detailed methods suitable for commercial use.

An interesting point is that the potassium content of the lepidolite may be turned to advantage as a source of potassium for fertilisers.

Three samples of lepidolite and petalite are being used in this research.

(3) Degree of Cure in Relation to Failure in Plastics and Paints.—Quite often in investigating failures in paints and some types of plastic resins there is very good reason to believe in many cases that the failure is due to imperfect or incomplete "cure" of the resin involved; there is, however, seldom any easy way of proving that this is in fact the case.

A good deal of library research on this problem has now been carried out, following which attempts are being made to devise suitable methods for determining degree of cure in thermoset plastics.

Causes of cure failure appear to be—

(a) errors in formulation;
(b) deterioration (perhaps through storage) of curing agents, catalysts, etc.;
(c) insufficient mixing;
(d) inadequate moulding cycles;
(e) incorrect-post-cure.

Methods of investigation currently being worked on may be summarised as:—

(i) Thermal analyses techniques.
  (a) Differential thermal analysis.
  (b) Standard exotherm curves.
(ii) Chemical techniques.
  (a) Acetone extraction.
  (b) Estimation of unreacted components.

Work along these lines is being pursued as other commitments permit.

(4) The Painting of Karri Timber.—It has been found necessary to confirm and extend the work previously done and reported on this subject. During the year preparations have actively gone ahead for the resumption of this work. Two new exposure stations, in addition to the one at Woodman's Point, are being arranged. One of these will probably be in the Mount Yokine Reservoir area where the atmosphere is classed as "residential"; the other will be in the Welshpool area and will provide an industrial atmosphere.

Work has been done on the design of suitable testing racks. A decision has still to be made on whether test fences should be used instead of racks. The tendency elsewhere in Australia, as well as in the U.K. and U.S.A., is now definitely towards test fences.

Preparations with respect to paint systems to be used and cognate matters are well in hand. A start should be possible early in 1965. Concurrent with this exposure work may be parallel work on polyester and other plastics specimens.

MINERAL, MINERAL TECHNOLOGY AND GEOCHEMISTRY DIVISION.

General.

Though the number of samples examined during the year (2395) was almost three hundred less than the record number registered for 1963, the figure was much the same as the average for the previous five year period.

The main sources of the samples were:—

General Public (free)	879
General Public (pay)	796
Geological Survey Branch	198
Departmental	167
State Batteries Branch	142

In addition to the Mines Department and its Branches, thirteen Government departments or instrumentalities submitted samples for examination.

TABLE 21.

Mineral Division.

	Public		Departmental	Geological Survey of Western Australia	State Batteries	State Mining Engineer	Public Works Department	Public Health Department	Local Government	Other Government	United States Navy	Total
	Pay	Free										
Aggregates	34	....	....	....	....	....	15	....	....	11	2	62
Alloys	23	....	....	....	....	....	....	10	....	2	....	35
Burnt lime	3	....	....	....	6	....	....	....	....	3	....	12
Clays	....	17	....	1	....	....	....	1	....	7	....	26
Corrosion	....	....	5	....	....	....	....	....	....	....	36	41
Dusts	10	....	27	....	....	....	....	38	17	4	....	96
Mineral Identifications	9	406	43	3	....	1	....	....	....	1	....	463
Minerals and Ores—												
Beryl	16	8	1	....	....	....	....	....	....	....	....	25
Copper	43	67	3	2	....	....	....	....	....	1	....	116
Gold Ores	254	143	....	14	....	....	....	....	....	....	....	411
Gold Tails	....	....	....	....	99	....	....	....	....	....	....	99
Gold Umpire	....	....	....	....	32	....	....	....	....	....	....	32
Gypsum	3	23	....	....	....	2	....	....	....	....	....	28
Heavy Sands	21	47	....	13	....	....	....	....	....	....	....	81
Iron	10	39	4	15	....	....	....	....	....	....	....	68
Lead	13	6	....	1	4	....	....	....	....	....	....	24
Limestone	9	2	....	....	....	....	....	....	....	....	....	11
Lithium	15	6	7	2	....	....	....	....	....	....	....	30
Manganese	3	10	6	25	....	....	....	....	....	....	....	44
Salt	8	....	....	....	....	....	....	....	....	....	....	8
Silver	88	2	....	....	....	....	....	....	....	....	....	90
Tantalite	8	6	1	1	....	19	....	....	....	4	....	39
Tin	67	16	3	....	....	....	....	....	....	....	....	86
Titanium	71	3	30	....	....	1	....	....	....	....	....	105
Tungsten	8	2	....	....	....	....	....	....	....	....	....	10
Vanadium	....	4	28	....	....	....	....	....	....	....	....	32
Arsenic	....	32	....	....	....	....	....	....	....	....	....	32
Others	33	34	5	71	....	2	....	....	....	2	....	147
Miscellaneous Investigations	46	1	3	20	1	....	15	2	....	17	....	105
Complete Analyses	1	5	1	30	....	....	....	....	....	....	....	37
	796	879	167	198	142	25	30	51	17	52	38	2,395

Staff.

No staff changes occurred during the year and only one brief field trip was arranged. This was to Mogumber where Messrs L. Hodge and A. J. Sims visited the site from which a mineral specimen had been submitted which had so far defied attempts to classify it. Further material was collected from which pure mineral is being recovered for further chemical and mineralogical examination.

An exhibition of minerals and mineral testing equipment was arranged at the Wembley Primary School during a fund raising fete being held by the Parents and Citizens Association. The display was arranged at the wish of the Hon. Minister for Mines and was manned by officers of this Division.

Mineral Collections.

At the end of the year the Mineral Division Collection contained 3,592 specimens representing an addition of 75 during the year.

Most of these were from localities within the State but 18 specimens originated from Broken Hill. These had been collected by the late Mr. J. Kelly of Kalgoorlie and were kindly donated to the Laboratories by his widow. The specimens consisted mainly of secondary silver, copper and lead minerals and included many spectacular examples of common and rare minerals typical of the oxidized zone of the Broken Hill ore bodies. Species represented included anglesite in interlocking crystals, azurite as large blue prismatic crystals, beudantite, the lead antimony sulphide boulangerite as radiating fibrous aggregates, chlorargyrite ($AgCl$), marshite (CuI), miersite (AgI), the lead tungstate stolzite with secondary wolframite, native copper as delicate arborescent forms and also as a large mass thickly coated with cuprite and thin films of paratacamite, and native silver as bright films on kaolin and as rich impregnations in smithsonite.

Three specimens from outside Australia were added to the collection as the result of an exchange requested by the Bureau de Recherches Geologiques et Minieres, Paris. These were fornacite from the Congo, yttrocerite from Finland and mansfieldite from France.

Specimens of local origin added to the collection will be mentioned later under Mineral Identifications.

Reorganising of the Simpson Collection has been completed. This collection, of almost 5,000 specimens, is now housed, classified and indexed in a manner which has greatly increased its value as a reference collection.

Eighteen sets of mineral specimens were prepared to meet requests for collections of typical W.A. minerals received from private individuals, schools and museums.

The discovery of gold in the form of telluride in Assam, India led to a request from that country for specimens of telluride minerals that could be used as standards for determinative work. The Division was able to supply the Director of Geology and Mining, Government of Assam, with specimens of coloradoite, calaverite, sylvanite, hessite and petzite for this purpose.

Building Materials.

1. Aggregates.—The testing of concrete aggregates continues as an important function of the Division. Work in this connection was carried out for the Public Works Department, Main Roads Department and the United States Navy as well as for a number of private contractors.

Six samples of river gravel are being subjected to detailed tests at the request of the Main Roads Department. The samples were taken in connection with the building of the Ashburton River bridge at Nanutarra. Four were essentially sands but the remaining two contained material up to 3 in. in diameter. A variety of rock types was present, most of which were common to all samples. Rocks and minerals present were sandstone composed of interlocking quartz, vein quartz, basalt composed of amphibole and feldspar, jasper, granite and some goethite. Thus no minerals known to be seriously reactive towards alkali of cement were detected and this was confirmed by the accelerated chemical tests for potential reactivity. However further confirmation was requested and a series of long range mortar-bar tests is in hand. After five months, no significant expansion has been recorded.

Aggregates examined for Public Works Department originated from the East Turner River near Port Hedland, and from Esperance. Nothing deleterious was detected in the shingle from the East Turner River. The samples from Esperance consisted of coarse and fine aggregate and soil. The aggregates were those used in a building showing signs of concrete swelling and the soil was from the building site. The presence of excessive amounts of gypsum, either in the aggregates or the soil, was a suggested cause of the trouble but chemical and mineralogical examination did not confirm the suspicion. The only deleterious matter detected was a possibly excessive amount of gross organic material in the sand.

Of six aggregates examined for the United States Navy, three were potentially reactive due to the presence of chalcedony and opal as cementing media for the predominant quartz grains.

Two rocks examined for private interests were composed in one case of coarse grained secondary quartz with a little chlorite and in the other of a fine grained intergrowth of feldspar, quartz, chlorite and epidote. The Mielenz, or accelerated chemical test, showed the latter to be innocuous but the one containing the secondary quartz was borderline.

Pit sands were examined for gypsum and water soluble salts. One sand required for the construction of a reinforced concrete tank was found to contain 0.49 per cent. of salts, mainly sodium chloride. As this concentration, in the mix proposed, was equivalent to using sea-water with a salt-free sand its use was not recommended for a reinforced structure.

A number of sands quarried in the vicinity of Perth have resulted in an undesirable degree of air entrainment in concrete. A suspected reason was a very thin organic coating on the grains rendering them hydrophobic. Treatment of the sand with organic solvents and infra-red examination of the resultant extracts by the Food and Drug Division gave some support to the theory but a lengthy research programme would be necessary to produce conclusive results. Sands causing air entrainment satisfactorily passed the Australian Standard test for excessive amounts of organic matter.

Two artificial light-weight aggregates were tested by the appropriate A.S.T.M. specification for such material and found to comply as regards the nature and amount of deleterious substances present.

2. Concrete and Mortar.—Concrete samples were tested for the Main Roads Department and private contractors to determine the original mix. Cement-sand segments from a soak well submitted by Public Health Department were found to have eroded badly due to a very weak mix.

A sample of concrete that was flaking off reinforced pillars of a school on the North West coast was submitted by Public Works Department for examination. Corrosion of the underlying reinforcing was severe and the concrete was of poor quality. The concrete contained 2.3 per cent. of water soluble salts, of which 0.5 per cent. was sodium chloride. This salinity, together with the porous nature of the concrete meant that the reinforcement was exposed to severe corrosion. The corrosion product, having a volume about twice that of the original steel, exerted stresses of sufficient magnitude to rupture the concrete.

Failure to harden of a newly laid cement floor in a fermenting cellar was suspected to have been due to copious flooding by beer. A sample was submitted for examination but when subjected to the test for sugar outlined in Australian Standard A77—1957 showed negative results. To determine the sensitivity of the test under these circumstances, mixtures of cement, sand, water and beer were prepared and it was found that no sugar could be detected when beer constituted 2.2 per cent. by weight of the mix but at 5.5 per cent. the reaction was positive. Beer present in excess of 1 per cent. very adversely affected the setting of the mix.

Analysis of a deposit on the cement lining of the Wellington-Narrogin water pipe was carried out for Country Water Supply. The one crystalline material in the deposit was calcite, most of the sample being amorphous in nature. Analysis indicated that most of the amorphous material was hydrated magnesium silicate. It is probable that this had been precipitated from the water by high local pH rather than from any deterioration of the pipe lining.

The specific surface of metal dust was measured for a private company.

3. Asbestos-Cement Pipes.—Eight samples of used water pipes from the metropolitan area were submitted by Metropolitan Water Supply Sewerage and Drainage Board for examination. These were of various makes and had been in service for periods varying from 6½ years to 16 years and a measure was required of the degree of deterioration suffered.

The examination was made by taking turnings at 1/32 in. intervals from the inner surface of the pipes and analysing chemically to determine the variations from the original composition at different depths. This would indicate the extent of leaching of lime from the pipes which is the most likely way in which weakening of asbestos-cement pipes would occur. Leaching was evident for depths of 1/16 in. up to ⅜ in., the magnitude of the leaching varying as much with the method of manufacture of the pipe as with the length of service.

4. Miscellaneous.—The gypsum content of a gypsum-lime plaster was determined, and two samples of "calcium silicate" were examined at the request of a firm manufacturing sand-cement masonry. One of these samples was satisfactory in practice but the other was suspected as the cause of poor blocks. Analysis showed them to be very different products chemically.

Of samples submitted as potential building stone the most striking was a "marble" specimen from the Kimberleys. It was composed almost entirely of calcite with a few scattered grains of detrital quartz. The calcite was present mostly as intergrown crystals but some concretions and traversing veinlets gave the rock its ornamental appearance.

Clay.

A pale buff coloured clay from N. Baandee vitrified at relatively low temperatures (1,000° to 1,150° C.) and burnt to a cream tough briquette of good shape and low shrinkage. It could find application in the manufacture of light coloured bricks or for use by potters.

Chloropal (nontronite) from Bridgetown had very poor firing characteristics but a white gritty clay from the same area could be of value in the brick and ceramic industries.

A sample from the Munglinup River area consisted of illite, kaolin and quartz. It had an Ashley figure of 193 but the absence of montmorillonite suggested it would be inferior to Marchagee bentonite as a decolourising medium.

Two clays were received from the Northam district. One containing over 1 per cent. of sodium chloride, did not burn satisfactorily but the other, a salt-free, light-buff clay containing about 50 per cent. grit behaved well on firing to 1,150° C. On drying out after wetting however, it showed some vanadium staining.

Other clays examined during the year originated from the vicinities of Bedfordale, Merredin, Salmon Gums, Karalee and Nookawarra Station.

Health Hazards.

A number of materials, mainly dusts, were examined with reference to their possible hazards to health. One, a bronzing powder, contained about 8 per cent. antimony in the form probably of metastibnite, an amorphous antimony trisulphide; another, a dust collected in the vicinity of a crusher in an industrial milling plant was mainly amorphous silica, not surprisingly in view of the fact that diatomite was the material being crushed.

Samples of settled dust were collected from the vicinity of a plant manufacturing slag wool. The dust was found to be composed largely of crystalline pseudo-wollastonite, a common ingredient of the blast furnace slag being used as raw material by the slag wool manufacturer.

Complaints were received by health authorities that men bagging copper concentrates were suffering abdominal symptoms. Examination of the concentrates revealed no lead or arsenic content and though residual flotation agents were present and resulted in a disagreeable smell no toxic properties have been attributed to these compounds.

A large number of dusts were examined for Public Health Department, Local Government authorities and the Fuel Technology Division. In most cases identification and size of the particles were required, with, in some cases, a particle count.

A concrete floor, reputed to be dusting despite treatment of the surface by a hardening compound, was examined at the request of the owners.

Calcite was found, after quartz, to be the major inorganic constituent of dust from the floor. However, as calcite also formed a considerable proportion of the outside airborne dust this evidence was inconclusive. As the surface hardening preparation alleged to have been used contained a fluorine compound the sweepings from the floor were tested for that element. No reaction for fluorine was obtained. Scrapings from the actual floor surface itself gave a positive fluorine reaction, leading to the conclusion that the concrete floor was not responsible for the dust problem.

Lime.

Of seven samples of burnt lime examined for the State Batteries Branch only one fell below 80 per cent. lime on the ignited sample. Also only one exceeded the 86 per cent. reputed to be the minimum specified.

Three hydrated limes were tested at the request of the Government Tender Board. All fell far short of the 95 per cent. on a non-volatile basis specified by the appropriate Australian Standard for the $CaO + MgO$ content.

Analytical assistance continued to be given to the Engineering Chemisty Division in connection with their work on the exploitation of lime sands.

Minerals and Ores.

1. Beryl.—Eight prospecting specimens of beryl were received, mostly from the North West and the Murchison areas. In addition, samples representing 16 sales parcels were assayed for BeO.

The largest tonnage originated from the Yalgoo G.F. with Coolgardie and Pilbara fields contributing most of the remainder. Parcels assayed between 10.7 and 12.5 per cent. BeO, averaging a little more than 11 per cent.

2. Copper.—Much of the copper work resulted from the continued search for ore of fertiliser grade (minimum 10 per cent. copper) or from attempts by individuals to up-grade sub-standard material for the same purpose.

The first involved analyses for both total and acetic acid-soluble copper. Attempts at up-grading were mainly by acid leaching of oxidised copper ores and in this connection the Division assisted with laboratory scale tests to determine the percentage of copper that could be extracted by this means as well as the consumption of sulphuric acid to be expected. The grade of the extracted sulphate was also determined.

In the copper samples submitted, the carbonate minerals were the most commonly encountered, two exceptions being a sample from Uaroo assaying 12.6 per cent. Cu, consisting of quartz and fine-grained mica with the basic sulphate, brochantite, as the main copper mineral and one from the Hall's Creek district assaying 11.9 per cent. Cu with chrysocolla the main source of the metal.

Some high-grade hand specimens were received, an example being a specimen from Copper Hills (between Nullagine and Marble Bar) assaying 72.8 per cent. copper and composed primarily of chalcocite with some malachite, cuprite and hematite. This sample was of additional interest in that it represented the first recorded occurrence of chalcocite from this locality.

A sample containing a wide range of copper minerals originated from Belele Station. As well as galena and talc, the sample contained malachite, chrysocolla, chalcocite, covellite, tenorite and chalcopyrite.

A sample of atacamite coating pieces of kaolin from Cardup quarries represented the first recording of atacamite in that area. A green mineral occurring as a stain or thin crystalline crust on fine-grained sandstone from Mt. Vernon proved to be paratacamite.

Thirty-six samples taken by a prospector interested in the geo-chemistry of the Wiluna area were analysed for copper. This work was done partly as a check on the prospector's own field determinations of the trace amounts of copper present and as a result advice was given on how to improve the accuracy of this field work.

Some particularly good specimens of copper minerals were collected by staff members visiting Ravensthorpe. Minerals collected included atacamite, covellite, chalcocite, digenite and cuprite.

3. Gold and Silver.—There was a considerable increase in the number of gold assays carried out, particularly on pay samples. This was due mainly to the increased prospecting activities of large companies with interests chiefly in base metals but not without an eye to a promising gold prospect.

Seventy-eight samples of concentrates from sand drillings were examined for total gold content and for identification of a heavy grey tail evident in some of the samples. Work on this grey material, which proved to be tungsten carbide, is described elsewhere.

Nodules from underground at Lake Grace, consisting of pyroxene, sericite, sphene, quartz and feldspar with traces of arsenopyrite and pyrrhotite assayed up to 5 oz gold per ton. A silvery mineral in the concentrate from the granulite of this area was forwarded as suspected telluride. Though gold was present, no tellurides were detected, the concentrate consisting mainly of arsenopyrite, pyrite, covellite, magnetite and some silicates.

Six ores for gold and silver were also assayed for antimony and arsenic as a guide to their behaviour when passed over battery plates.

A number of samples were examined from abandoned dumps in the Wiluna area. A test carried out showed a 20 per cent. yield from a 5 dwt. sand when subjected to cyanidation without further grinding.

For the Geological Survey, five samples were assayed from the No. 3 level of the Pinnacles Mine near Cue, and five for both gold and silver from the Mangaroon Star on the Gascoyne G.F.

There was a big increase in the number of silver assays reported. Though most of these were on potential gold and silver ores, a number were carried out on lead-zinc ores.

4. Gypsum.—The number of gypsum samples received was little less than in the previous year, many being submitted due to the continued campaign to convince farmers of its fertiliser value.

Until some conclusive scientific evidence is produced to establish that W.A. soils are deficient in sulphate or calcium the man on the land may well find no return for his money by adding gypsum to his soil. The value of gypsum as a conditioner on some soil types is well established but for this use it can scarcely be regarded as a fertiliser.

Samples were received from Lake King, Lake Carmody, Newdegate, Salmon Gums, Hopetoun, Lake Wallabin, Kondinin and Dongara. Of the better grade material one from the Lake King area assayed 97 per cent. gypsum though most samples varied between 85 and 93 per cent.

A grey mud from Kondinin, in addition to gypsum, contained organic matter, clay, calcite and anerobic sulphides.

A rather striking example of high-grade material originated from a cave about 10 miles north of Madura Pass.

At the request of the State Mining Engineer the bulk density of Dongara gypsum was measured. In lump form the figure was 101 lb/cft whereas a powder variety, bulked, uncompacted was little more than half this figure, namely 53 lb/cft.

5. Heavy Sands.—There was a considerable increase in the number of heavy sand samples submitted during the year, namely 81 compared with 31 in 1963. Though the mineral sand industry is well established, considerable interest is evident in the search for further reserves.

An unusual number of heavy sands were received from inland areas, including Narrogin, Babakin, Wojerlin, Kulin, Mt. Magnet and Napier Downs Station in the Kimberleys. Most samples however originated from coastal deposits, localities including Hopetoun, Wilson's Inlet, Windy Harbour, Parry Inlet, Busselton, Chapman River, Onslow and Broome.

Though iron or titanium minerals made up the bulk of the heavy mineral fraction in most cases, the heavy fraction of sands from Parry Inlet, Windy Harbour and Chapman River was predominantly garnet.

Ten beach sands were fractionated at the request of a mining organisation. Heavy fractions were isolated using liquid of specific gravity 2.95 and the fractions further split into magnetics and non-magnetics. Quantitative mineral identifications were carried out and appropriate fractions analysed for titanium and chromium contents.

Twelve samples from exploratory water boreholes in the Wicherina area were examined for heavy minerals at the request of Geological Survey. Minerals identified were goethite, hematite, magnetite, pyrite, leucoxene, zircon and tourmaline. One sample contained 2.51 per cent. of heavy minerals but no other contained more than 1 per cent.

6. Iron.—Fewer iron ore samples were handled than in the previous two years though a request for several hundred assays by a company drilling in the Mt. Newman area had to be refused due to staff limitations.

The most detailed work on iron ores was carried out for the Geological Survey. Nine samples from Ophthalmia Range were assayed for iron, silica, alumina, phosphorus, sulphur, titanium, manganese, copper and combined water. Iron figures ranged from 60.5 to 69.1 per cent., copper from 20 to 50 ppm. Similar work was done on four ores from the Hamersley Ranges, two being pisolitic limonites from Dales Gorge, one a massive hematite from Mt. Lockyer and one a platy hematite-goethite ore also from Mt. Lockyer.

Three samples representative of deposits of Robe River ore were subjected to virtually complete analyses as these were to represent the head samples for up-grading work being carried out by the Engineering Chemistry Division. Microscopic examination established that the quartz grains present in ore from the upper section of the deposit averaged about 50 microns in diameter, with a maximum about twice this figure, whereas in ore from the lower section, practically all quartz grains were less than 50 microns across. Subsequently products from beneficiation tests on this ore were examined microscopically and chemically.

Three iron ores from the Mt. Gibson area were examined. Two were essentially hematite, the third magnetite. All three showed traces of apatite together with appreciable amounts of a hydrous iron silicate mineral which has not yet been identified. The x-ray diffraction pattern is strong but matches nothing in the current A.S.T.M. index. Further work will be done on this mineral as opportunity arises.

Thin sections were prepared for commercial interests from bore cores from the same area. These sections revealed the presence of talc and some quartz in addition to the iron minerals. None of the unidentified iron silicate was present.

Specimen material was received from all parts of the State. A magnetite from Paynes' Find assayed 69 per cent. iron.

Stilpnomelane was an iron mineral of interest identified in the Brockman iron formation of the Hamersley Ranges.

A talc-like mineral, suspected of being the iron silica minnesotaite, was identified as massive muscovite.

7. Lead.—With the revival of interest in lead more lead samples were received than in the previous year.

Two samples from the Northampton area, containing mainly galena, with some anglesite and cerussite each assayed about 2 oz. of silver per ton. Though galena from a number of localities in the North-West has carried from 10 to 100 oz. silver per ton we have no previous record of galena from the Northampton field assaying higher than 10 dwt. per ton.

Other samples received from this field were analysed for zinc and lead, being mixtures mainly of blende and galena. Lead and zinc were also determined on a number of products from the reopened Devonian lead mine in the West Kimberleys. Minerals present in some samples from the latter source included cerussite, smithsonite, hydrozincite, malachite and azurite.

Samples from Mt. Joseph in the Kimberleys were mainly quartz and baryte but contained also pyrite and galena.

Galena was associated with malachite and chalcopyrite in specimens from Lyndon Station. A member of the pyromorphite-mimetite series of lead chloro-minerals was received from Uaroo.

8. Lithium.—An overseas demand exists for lithium ore with a lithium oxide (Li_2O) content of 4 per cent. or better. Japanese consumers during the year were seeking 100 tons per month of lepidolite with a minimum of 4 per cent. Li_2O and a maximum iron content of 0.05 per cent. Of the two figures, the iron maximum is probably the more difficult to meet from local sources. For example, sheet lepidolite from the General Foch mine at Grosmont had the extraordinarily high Li_2O figure of 6.01 per cent. but the iron content was 0.38 per cent. Other lepidolite samples, from Londonderry, Poona, Marble Bar and Wodgina assayed between 2.2 and 4.6 per cent. Li_2O.

The lepidolite samples examined varied in colour from pale violet to almost black but the depth of colour bore no relationship to the lithium content. On the other hand, a few samples analysed for manganese showed the intensity of the colour to increase with the manganese content. However, a pale lepidolite mined from underground will darken appreciably on prolonged exposure on the surface without necessarily any alteration in manganese content. It is therefore probably more correct to conclude that the colour of a lepidolite depends on the oxidation state of its manganese content rather than on the total amount of that element present.

A purple specimen received from Wodgina proved to be oncosine (fine grained compact cryptocrystalline muscovite), the colour again being due to traces of manganese. The Li_2O content was 0.26 per cent.

The existence of a complete series between muscovite and lepidolite is now generally accepted by mineralogists, the polymorphic variations being correlated with chemical composition, particularly the lithia content. Normal muscovite may have as much as 3.3 per cent. of Li_2O. A lithium—bearing muscovite from Davyhurst was received through the Geological Survey. It had the general appearance and colour of platy lepidolite, but X-ray powder data indicated a similar structure to normal two-layer muscovite. Its lithia content was 2.93 per cent.

Analyses were carried out on commercial parcels of petalite from the Londonderry quarries, but aside from these only one specimen of petalite was received. This originated from the Dalgaranga pegmatites which were first known to carry this mineral only a year or two ago.

Amblygonite from the long known deposit at Ubini and a lithium phosphate mineral near the montebrasite end of the montebrasite-amblygonite series from Ravensthorpe were the only other lithium minerals received.

9. Manganese.—The majority of the manganese ore samples examined during the year were submitted by the Geological Survey.

Eight bore cores from a Woodie Woodie claim contained a range of manganese minerals. As well as cryptomelane, braunite and pyrolusite all contained a mineral with optical and X-ray properties resembling those of the zinc—manganese oxide chalcophanite. Chemical examination revealed only traces of zinc and though zinc can be replaced by both manganous manganese and ferrous iron such substitution is never complete. The absence of appreciable amounts of zinc therefore makes the true classification, of this mineral uncertain and as it is finely disseminated throughout the ore not sufficient pure sample could be isolated to allow of detailed and accurate chemical work.

The mineral hausmannite (Mn_3O_4), though it had been recorded by other workers as occurring in the Mt. Sydney manganese deposits, has never been identified in W.A. ores examined in these laboratories. Samples from the floor of the main quarry at Mt. Sydney were supplied by the Geological Survey but neither X-ray nor polished mount work revealed any hausmannite in these samples. They consisted primarily of braunite with hematite, cryptomelane, pyrolusite and minor ? chalcophanite.

Analyses were made for manganese, iron and silica on a number of ores. Manganese minerals, predominantly cryptomelane, were identified in samples from Desmond, Day Dawn, Coolgardie, Wodgina and Hawkins Knob.

Other analytical and mineralogical work was carried out on products submitted by the Engineering Chemistry Division in connection with that Division's work on up-grading of manganese ores. These products were mainly the result of reduction roasting of the original ore. One product was shown by X-ray diffraction work to be manganous oxide, the artificial equivalent of the mineral manganosite while a second sample was identified as mangano-manganic oxide, Mn_3O_4 the artificial equivalent of hausmannite.

10. Salt.—Salt being harvested from a potential new inland source was examined for impurities at the request of the producer. The results showed impurities, as calcium and magnesium salts, of 1.2 per cent. It was found that about half these impurities could be removed by washing with its own weight of saturated brine. A higher brine to salt ratio did not improve the up-grading.

Three other salts and one brine from the same source were subsequently examined and the salts compared by analysis with material known to be commercially acceptable for hide curing. There was no evidence of a chemical nature to suggest any difference in curing properties and any differences shown in practice are more likely to be due to differences in salting techniques, that is, to human factors rather than chemical ones.

Two salt samples were analysed for the Wyndham meatworks.

11. Tantalite-Columbite.—Less than half as many tantalum bearing minerals were received as in the previous year, reflecting the marked weakening of the market for those minerals during that period.

Only four samples representing commercial parcels were examined though a number of test products were received from firms investigating potential deposits and from the School of Mines, Kalgoorlie.

Nineteen samples from the Dalgaranga fields were submitted by the State Mining Engineer. Two of these were concentrates and were analysed for Ta_2O_5 and Nb_2O_5; the remainder were samples of potential ore. By appropriate chemical and heavy liquid treatments, concentrates were obtained from the latter of heavy minerals free from iron oxides. These were weighed and examined mineralogically. Ilmenite and tantalite-columbite were common to about two-thirds of the samples with minor amounts of rutile, zircon and garnet. Six of the heavy mineral concentrates were chiefly silicates with only very minor amounts of opaque oxides.

A specimen of interest was received from the Pilbara area. It was a columbite so intimately intergrown with muscovite mica that its specific gravity was only 4.81. Another unusual association was columbite in a matrix of calcite with minor amounts of quartz, clay and garnet. This specimen was found near Turkey Creek.

A black pegmatite mineral from the abandoned MHL 28 at Ravensthorpe was shown by X-ray diffraction to be microlite. The calcium antimony titanate, lewisite, has been reported from this pegmatite and in an endeavour to isolate this mineral a number of samples have been taken from the lease but to date all suspected minerals have proved to be microlite.

12. Tin.—Most tin assays were on concentrates though a number of very low concentration samples were analysed as potential ores or geochemical indicators, as well as a few tin-bearing products from various stages of experimental beneficiation tests.

Samples received, other than sales parcels, included a limestone from an undisclosed locality consisting of calcite, feldspar, quartz, hematite and cassiterite, assaying 4.4 per cent. tin; a rock of feldspar and quartz with a little tourmaline and cassiterite, assaying about 2.6 per cent. tin, and from Poona a kaolin, with some quartz and mica, carrying 0.9 per cent. tin as cassiterite.

Two prospecting concentrates contained significant amounts of monazite, one from the Binneringa field east of Widgiemooltha carrying between 8 and 10 per cent. and the other, from Abydos, showing about 5 per cent. monazite.

A clean sample from the Nullagine district, containing many well-defined cassiterite crystals, showed a 97 per cent. cassiterite content on the zinc dish test but assayed chemically only 87.7 per cent. tin dioxide. Time has not been available to follow this up in detail but it is undoubtedly another instance of intimate intergrowth of other minerals, probably columbo-tantalite, with cassiterite which has been experienced before in concentrates from some areas of the Pilbara.

W.A. tin producers can now elect to be paid on the figure obtained by averaging the buyer's assay with that of this Division whereas in the past they had little choice other than to accept the buyer's figure. This arrangement has resulted in an increasing number of samples being received representative of commercial parcels.

Agreement in analytical figures has, on the whole, been good, only four out of 47 differing by greater than 0.5 per cent. tin. Nevertheless disagreements even to this extent justify the continuance, as time permits, of the investigational work, on analytical methods commenced in 1963 and reported in the Annual Report for that year.

Two samples, on neither of which two experienced analysts could obtain consistent figures, were compared spectrographically with a third sample from the same batch which had caused no analytical problems. Of the major metallic constituents, all (tin, iron and manganese) fell in the same ranges, as did the minor (up to 1 per cent.) elements aluminium, cobalt, copper, nickel and titanium. Arsenic, antimony and bismuth were not detected in any of the samples.

The only elements that appeared in greater concentration in the two troublesome samples than in the normal one were tantalum and niobium. And yet cassiterite samples to which small amounts of columbite and tantalite had been deliberately added caused no problems and gave figures which indicated that these elements did not interfere in the determination of tin by the standard iodate method.

Investigational work further emphasised the necessity for rigid standardisation of procedures during the standardising of solutions and the actual assay. One illustration of the importance of this was obtained by figures which showed that significant errors could be introduced if the types of nickel used in standardisation and assaying are not identical, even if both are pure.

Miscellaneous Analyses.

1. Mineral. (a) Partial.—Samples of molybdenite from Mt Mulgine and Eleys were supplied by request to the Australian Institute of Nuclear Science and Engineering, Lucas Heights. The Institute was making a survey of the rhenium content of Australian molybdenites: figures reported on the above Western Australian specimens were of the order of 15 ppm and 2 ppm respectively.

Twenty ore samples were analysed for nickel. Six of these were for the Geological Survey and originated from the Warburton Range area. The same samples were assayed for cobalt and showed a fairly consistent nickel to cobalt ratio of the order of 10 to 1.

Seven samples were analysed at the request of a private consultant for fluorine, tungsten and molybdenum. None of these elements were present in amounts greater than one per cent.

Most vanadium analyses were in connection with work by Engineering Chemistry Division on the up-grading of Coates vanadium ore. The two ore types being considered were the unaltered gabbro from about 100 feet underground and the weathered surface material. Titanium and iron, as well as vanadium, were determined on a number of test products from each and the distribution of vanadium throughout various size ranges of the weathered ore determined. Analysis of a sample representative of the unaltered ore is reported under Complete Analyses.

Shipment samples of zircon concentrates were analysed for zirconia, titania, alumina, ferric oxide, phosphorus and silica. Another concentrate was examined microscopically for impurities, which were found to be rutile, kyanite and quartz in trace amounts. The zircon grains contained numerous minute inclusions and an attempt was made to determine whether these were titanium bearing. Attack on the uncrushed sand by molten bisulphate gave an extract with a strong titanium reaction, but similar treatment of the finely crushed bisulphate residue gave an extract with no titanium reaction indicating that the inclusions were not titaniferous. They may well be predominantly gas bubbles.

Other products from operating beach sand plants were also analysed. Determinations included rare-earths and thorium.

Seven potential glass sands from Lake Gnangara were sized and analysed for iron, silica and ignition loss at the request of the Geological Survey. The silica content varied from 98.6 to 99.8 per cent., iron from 0.02 to 0.17 and loss on ignition from 0.06 to 0.76.

A number of prospecting samples were analysed for phosphorus, nickel, vanadium, cobalt, and one for germanium.

Six samples from abandoned mine residues were analysed for lead, bismuth, arsenic, antimony, iron and gold.

Two baryte samples were examined for compliance to paint trade specifications. Determinations included barium, iron, silica, magnesia, lime, carbon dioxide, sulphate and water soluble salts. Neither sample met requirements.

A sample representing a commercial parcel of bismuth ore was analysed for its bismuth content.

Two products resulting from attempts to recover scrap lead from old batteries were fractionated into metallics and non-metallics and assayed for lead, antimony and sulphate. As a result, improved methods of recovery of metallic lead were suggested.

(b) Complete.—Eighteen complete analyses of rocks and minerals were reported during the year, mainly to the Geological Survey.

One batch of nine rocks originated from the Mt. Bruce and Robertson areas and comprised an acid lava, two siltstones and five acid volcanics.

Five rocks from the south coast, consisting of basic granulites and gneisses, were analysed for the University Department of Geology as part of that Department's current research programme.

An unaltered gabbro from Coates Siding and a sample of ilmenite sand from Queensland were analysed in detail as these materials represented the head samples used in research projects at the Engineering Chemistry Division.

Analysis of the vanadium bearing gabbro from Coates Siding gave the following results:—

	Per cent.
Silica, SiO_2	29·5
Alumina, Al_2O_3	12·7
Ferric oxide, Fe_2O_3	20·8
Ferrous oxide, FeO	16·6
Magnesium oxide, MgO	2·71
Calcium oxide, CaO	5·78
Sodium oxide, Na_2O	1·64
Potassium oxide, K_2O	0·28
Lithium oxide, Li_2O	not detected
Combined water, H_2O+	2·28
Free water, H_2O-	0·39
Titanium dioxide, TiO_2	5·92
Phosphorus pentoxide, P_2O_5	0·02
Iron sulphide, FeS_2	0·64
Manganese oxide, MnO	0·18
Vanadium trioxide, V_2O_3	0·43
	99·87

Analyst—P. Hewson.

Minerals of unusual interest continue to be received from the Mt. Vernon area. Last year analytical figures were reported on an uncommon pickeringite-epsomite series from this locality. Subsequently, the Geological Survey submitted a specimen from near the Mt. Vernon homestead which consisted mainly of fine-grained sandstone in association with two green minerals. One of these green minerals, occurring mainly as a stain, but in places as a green crystalline crust proved to be paratacamite, the rhombohedral basic copper chloride. The other was identified as variscite and occurred in the form of veins in the sandstone. An analysis of a purified sample of this vein material gave the following figures:—

	Per cent.
Silica, SiO_2	0·78
Alumina, Al_2O_3	29·81
Ferric oxide, Fe_2O_3	2·65
Ferrous oxide, FeO	*nil*
Total water, H_2O	24·38
Phosphorus pentoxide, P_2O_5	42·70
	100·32

Analyst—J. Gamble.

2. Alloys and Metals.—The greatest number of samples under this heading consisted of white metal for determination of lead, tin, antimony and copper.

The "silver" of metallic braid was shown to consist of a copper-nickel alloy.

The containers of eight out of ten tooth paste samples submitted by Department of Public Health were found to be aluminium but the remaining two were manufactured from a lead-tin-antimony alloy.

The thickness of the anodised film on four aluminium window fittings was measured at the request of Public Works Department. These thicknesses had been measured by the suppliers using the voltage breakdown method and a check was required using the more direct micro-section referee method. The results showed good agreement between the methods at low thicknesses up to 5 ten-thousandths of an inch but above this figure and in the vicinity of the specified 10 ten-thousandths of an inch the voltage breakdown procedure gave results between 30 and 50 per cent. too high.

Mineral Identifications.

1. Miscellaneous.—This section lists mineral identifications not already described under Minerals and Ores.

Talc specimens were received from a number of localities, including Bullfinch, Mullewa, Coorow and Belele Station. One sample from Belele was of good quality, crushing to a white powder. Another from the same area occurred as an accessory in a specimen containing malachite, chrysocolla, chalcocite, covellite, tenorite, chalcopyrite and galena. The three specimens from Coorow were of fair quality but not up to the standard of the best Three Springs material.

A sample from Melville consisted of grey to amber scheelite with some fragments of bismutite. One from two miles east of Cue was predominantly wolframite. A specimen of commercial grade bismutite containing a little residual bismuthinite was received from the Marble Bar area.

Samples of Brazilian quartz received represented the two grades acceptable to U.K. producers of fused silica ware. The Grade I material consisted of quartz fragments showing no crystal faces, of high transparency and with no visible flaws. Grade II showed slight translucency due to numerous random flaws. Thin sections of both grades showed numerous inclusions from 1 to 10 microns in diameter. The quality of local quartz received during the year fell far short of this overseas material.

Mottramite, occurring as a thin layer on quartz, was identified in a specimen from Mangaroon.

A specimen of smithsonite, containing also blende, pyrite, arsenopyrite, galena and chamosite was received from the Devonian lead-zinc mine on Napier Downs Station in the West Kimberley.

A purple calcite, with chlorite and quartz, originated from Mt. Magnet.

Large spherulite type concretions of radial structure from the coast south of Northcliffe were found to be composed of calcite with a central void lined with calcite crystals.

A magnesian chalybite was identified occurring with fuchsite and a little pyrite from Albert's Deeps, at Meekatharra.

A striking fuchsite specimen from two miles south of Payne's Find consisted of micaceous flakes containing minute crystals of rutile. It occurred associated with garnets, lepidolite and zinnwaldite.

Garnet crystals, coated with fine mica, were received from Mt. Broome in the Kimberley and predominantly garnet sands were received from Sandy Island off Windy Harbour and from the mouth of the Chapman River. The latter contained about 65 per cent. of pink garnet.

Samples of altered garnet from Roebourne showed anomalous optical properties and were classified mainly on X-ray diffraction evidence. Another sample from the same area, though pink in colour could only be classified as an altered epidote on X-ray evidence.

A massive fine-grained muscovite from Yarrie Station was of interest as a possible medium for sculpture.

Stones of ornamental interest were mainly siliceous. Amongst these were fine-grained green quartz from Moorarie Station and Roebourne and a translucent greenish quartz with chalcedony from Soda Springs on Argyle Downs Station. Attractive trinkets could possibly have been cut from an opalised asbestiform amphibole from Yoothapina Station and from a quartz replacement of a similar type of amphibole from the Capricorn Range.

An epidotised granitic rock of quartz, epidote, feldspar and chlorite, in which epidote had replaced most of the feldspar, was received from Karlgarin.

A sample from Moogooree Station was composed of fragments of staurolite, corundum and epidote, with quartz geodes and limonite pseudomorphs after pyrite. A sample from Koolanooka, which at first sight appeared to be an ordinary ironstone gravel proved to be a mixture of corundum, gibbsite and magnetite.

Chromium bearing clays were received from the Corrigin area while pyrophyllite was recorded from Tabba Tabba and, for the first time, from three miles north of Coolgardie.

A large number of specimens of iron ore were sent in for identification and covered the whole range of commercial oxides. Goethite provided the most spectacular specimens, two such being a highly iridescent specimen from Stockyard Creek on the Ashburton and a fibrous sample from Mt. Jackson.

Massive ilmenite originated from near the Moyagee Railway Siding. Cassiterite, to the extent of about 3 per cent. occurred in a quartz feldspar tourmaline rock from Big Bell.

High grade cuprite from the Uaroo Station occurred together with brochantite and malachite.

Good quality baryte was received from the Yalgoo area. A sample from Mt. Hart in the West Kimberley contained baryte associated with quartz, goethite and jarosite with small amounts of pyrite, galena and anglesite.

A few fragments of columbite, rutile, manganese-ilmenite and niobian rutile were received amongst a fragmented, predominantly iron ore sample from Cue.

Other minerals of interest, included purple fluorite coating fine-grained feldspar from the vicinity of Dalgouring, and monazite from Pilgangoora.

A sample received from an undisclosed W.A. source proved to be romeite (calcium antimonate) with antimony oxides probably in the form of valentinite and cervantite. A little quartz and pyrite were also present. A representative portion of the specimen assayed 66.7 per cent. antimony.

A scoriaceous mass of material mixed with red soil was received through the Geological Survey and was stated to be of common occurrence in the Widgiemooltha area. The sample was composed of inhomogeneous glass which melted between 1,000°C and 1,100°C. Physical and chemical examination gave results that discounted its being a fulgurite, meteorite, impactite or smelting residue. A theory could be advanced that it was a material resulting from the fusion during bush fires of inter-root soil under the fluxing action of wood ash, clay micas and feldspars.

2. New Species.—Two species not previously described from Western Australia, perite and wodginite, were examined in some detail. Perite is an extremely rare oxychloride of lead and bismuth occurring at the type locality of Langban in Sweden. In 1940 this mineral, which was unnamed and similar in appearance to the lead chlorarsenate ecdemite, was found to contain bismuth. It was not until 1960 that the mineral was fully described, when Marianne Gillberg, named it in honour of Prof. Per Geijer, a well known Swedish geologist.

A sample from Maroonah Station sent in by Mr. E. Munns, contained chiefly quartz and galena with a little cerussite. Three small patches of a soft yellow mineral were found adhering to the galena.

Identification was a problem but the data obtained suggested perite as a possibility. Not sufficient material was available for detailed quantitative chemical analysis, nor had an X-ray diffraction pattern been published, but verification that the mineral was in fact perite was obtained by using a recently published method for producing synthetic perite. The X-ray patterns of the unknown mineral and this synthetic product were identical.

Spectrographic examination showed lead, bismuth and, in lesser amount, antimony as major components, with copper, iron and silver as minor components and spectrographic traces of aluminium, boron, calcium, magnesium, silica, titanium and vanadium. Tellurium was present but in undetermined amounts and is possibly combined with the silver.

Microchemical qualitative tests gave strong reactions for lead, bismuth and chlorine and a weak reaction for antimony.

It is proposed to publish a paper on this occurrence when all possible data have been accumulated.

Wodginite, a new monoclinic tantalite, was identified in samples from Wodgina, Marble Bar and Tabba Tabba. For details, see under report by Physicist and Pyrometry Officer.

3. New Localities.—Minerals for which new W.A. localities were recorded in 1964 are listed below.

Mineral	New locality
	(a) Kimberley Division
Chamosite*	Devonian Mine, Napier Downs.
Jarosite	Mt. Hart.
Baryte	Mt. Hart.
Pyrite	Mt. Hart.
Galena....	Mt. Hart.
Anglesite	Mt. Hart.
	(b) North-West Division
Mottramite	12 m. N.E. of Mangaroon Homestead.
Chalcocite	6 m. N. of Nullagine.
Corundum	12 m. S.E. of Moogooree Homestead.
Beryl	12 m. S.E. of Moogooree Homestead.
Pyrophyllite	Tabba Tabba.
Brochantite	4 m. S.E. of Uaroo Homestead.
Wodginite*	Wodgina.
Wodginite*	Tabba Tabba.
Wodginite*	Marble Bar.
Ixiolite	Tabba Tabba.
Perite*	20 m. N.E. of Maroonah Homestead.
	(c) Murchison Division
Columbite	8m. N.N.W. of Mt. Charles.
Baryte....	20 m. S. of Yalgoo.
Clinozoisite	Yarrabubba Station.
Chromite	Cue.
	(d) South-West Division
Talc	Mt. Gibson.
Molybdenite	17 m. N. of Dalgouring.
	(e) Central Division
Pyrophyllite	3 m. N. of Coolgardie.
Cassiterite	Binneringa Station.
	(f) East Division
Gold	Lake Baker.

* The minerals marked with an asterisk are recorded for the first time as occurring in Western Australia.

4. Spurious Minerals.—A series of ores from Mt. Margaret district were submitted for gold assay and identification of a heavy grey metallic mineral observed in the panning dish.

An initial diagnosis by an x-ray diffraction pattern suggested a fine grained mixture of the artificial tungsten carbides W_2C and WC in approximately equal proportions, the source of which would most probably be the hard tips of drills used in mining.

Tungsten was proved chemically and the yellow ignition product was shown by x-ray to be pure WO_3. Further confirmation was obtained by comparison of the x-ray diffraction patterns of the material and of fragments from the end of a tungsten carbide tipped tool.

However the sample crushed readily in an agate mortar which was puzzling in view of the extreme hardness of tungsten carbide tips. It was concluded that the inferior hardness of the sample was due to the presence of W_2C in the compound, perhaps along the WC crystal boundaries or as finely disseminated conversion products produced by metal crystallisation with age or impact during drilling.

A strikingly crystallised specimen of unknown origin donated to the Division proved to be the calcium aluminium silicate, gehlenite. Though there was no way of proving beyond doubt that the material was of artificial origin, the complete absence of associated minerals, together with the fact that gehlenite is a common constituent of slags, rather suggests that it is not a natural occurrence.

A specimen with the appearance of opal and having somewhat similar optical properties proved to be an organic compound of artificial origin.

Other specimens received under this heading included metallic antimony found five miles north of Albany, glass from Mt. Barker and the Murchison area and ferrosilicon from Payne's Find.

"Dung bitumen", the hardened extract of marsupial or bat guano, commonly found in the drier areas of the State, was identified from the Murchison River "loop".

5. Fossils.—Four fossils were received during the year. One consisted of brachiopod shells from Williambury Station; another was a particularly fine specimen of a fossil sponge from the Ravensthorpe spongolite quarry. A calcitic remnant of portion of a member of the belemnoid family originated from Peedamullah Station.

Miscellaneous Investigations.

1. Punch Card Index.—During the period 1959-1961 nearly 500 new mineral names were proposed. Of those almost 150 were accepted as valid species and were added to the imposing list of approximately 4,000 such minerals. The remaining names were relegated to the list of over 10,000 varietal names which plague the mineralogical literature.

This type of increase means that as each new text book of mineralogical data is published it is immediately out of date, which may account for the fact that new texts in this field are few and far between.

A punch card system has been developed in the Division which records and makes readily available all current data as they appear in mineralogical periodicals.

2. Reflectivity of Minerals.—In recent years the designing of sophisticated instruments for quantitative measurements in reflected light microscopy has led to an upsurge of interest in ore microscopy, and it can be said that the quantitative stage is now being approached that was achieved over 50 years ago with transmitted light microscopy.

A micro-reflectometer with its attendant extra high tension stabilised power supply has been designed and nearly completed by members of this Division. This device will enable quantitative measurements to be obtained from grains as small as 20 microns in diameter and in conjunction with a proposed micro-hardness testing instrument should form the basis for using the new quantitative data that has been published over the last few years.

3. Mineral Separations.—A suite of nineteen rock specimens was submitted by the Geological Survey for the preparation of 31 pure samples of minerals that occurred in the rocks. The pure samples were to be analysed by the Bureau of Mineral Resources after use for optical work by the Survey.

The minerals required were garnet, biotite, amphibole, pyroxene, epidote and spinel. The mineral crystals in the rocks appeared coarse grained but were found to be full of inclusions or finely intergrown. Crushing to minus 200 mesh was found to be necessary to break up the composite particles.

At this fine state of subdivision all heavy liquid separations had to be carried out in small amounts with centrifuging, while electromagnetic separation work had to be repeated many times to get good results.

Initial concentration was carried out with bromoform, S.G. 2.85, to remove feldspar and quartz. Biotite was floated from garnet and pyroxene, and amphibole floated from pyroxene and ilmenite with methylene iodide, S.G. 3.25. Pyroxene was separated from spinel and garnet with Clerici solution at a specific gravity of 3.7 and garnet from ilmenite with the same solution concentrated to S.G. 4.33. Epidote and pyroxene were separated from each other by repeated passes through the Frantz isodynamic separator.

4. Others—Cores from 14 diamond drill holes were submitted by Public Works Department for determination of hardness and grain size. The samples were sandstones from Broome harbour, consisting essentially of quartz grains weakly cemented together with a mixture of indurated clay, mica and iron oxides. The grain size of the quartz was fairly uniform throughout any sample, though ranging from averages of 80 microns to 300 microns throughout the suite.

Three surface rocks examined for relative weathering all consisted of plagioclase, microcline, quartz and biotite with small amounts of hornblende, ilmenite, limonite and epidote. The weathering, as judged from the cloudiness of the feldspars, was not considered significant and it was concluded that the Los Angeles abrasion test number would not appreciably improve with depth.

The quartz content of a quartz-chlorite rock was determined at the request of a company concerned in drilling the rock. The compay had the impression that the drillability of a rock could be directly correlated with the quartz content but it was pointed out that a large number of other variables were also involved, including grain size and shape, nature of binding materials and specific gravity. The only satisfactory method that has been developed to compare drillability of different kinds of rock is the direct measurement of the relationship between the load applied to a test drill and the speed of penetration under ridgidly controlled experimental conditions. Though such testing apparatus has been developed, no W.A. laboratory is equipped with it.

A further batch of 36 wires from exposure tests being conducted at N.W. Cape by the U.S. Navy were examined for the nature and extent of corrosion.

PHYSICS AND PYROMETRY SECTION.

The work of this section will be described under the three headings *Pyrometry, Thermal Methods* and *X-Ray Methods.*

Pyrometry.

A long copper-constantan thermocouple was calibrated in the range 0 to 50°C. for departmental study of atmospheric temperature inversions at low altitudes. Difficulty was experienced with background noise due to electromagnetic induction along the 500 foot couple, but this was satisfactorily overcome by the use of large value capacitors to shunt the alternating current to ground, and it is believed that this method could be used for low altitude measurements in the absence of telemetry devices.

Four National Association of Testing Authorities certificates were issued during the year for the calibration of mercury in glass thermometers. The total range of temperature covered was 0 to 100°C. at ± 0.1°C. In addition to this, one optical pyrometer was given a spot check at two temperatures in the range 900°C. to 1,500°C.

Temperature measurements were carried out in the drying kilns of a commercial brickworks. The temperature distribution was investigated along each kiln and in various positions in the stacks to investigate the drying conditions of the bricks. This is more completely described in the report of the Fuel Technology Division.

A base metal thermocouple was constructed and calibrated in conjunction with a potentiometric recorder for Industrial Chemistry Division. This was to be used for recovery of lithium from petalite, which is described in the Industrial Chemistry Division report and referred to in the following section.

Thermal Methods.

A commercial internally wound furnace was installed in the differential thermal apparatus in June and satisfactorily tested. The power capacity and thermal lagging are adequate to maintain a 10°C. per minute rise rate to 1,100°C. with gradual decrease thereafter to a maximum allowable temperature of 1,300°C. Alternatively, 20°C. per minute can be maintained to 900°C. with gradual decrease thereafter. The higher rise rate is used for rapid routine work, and the standard 10°C. per minute or slower 5°C. per minute are used for special studies as required.

Some examples of the type of problem studied by this method are given below.

(1) Several thermograms were obtained of the reduction of iron ores with coal char for the Engineering Chemistry Division. In a dynamic atmosphere of nitrogen, reduction endotherms were observed in the range 800-1,000°C. In general, these peaks were multiple, as shown in Figure 8. Interaction of carbon and iron with the thermocouple platinum is a source of spurious peaks at high temperatures, and further tests are being carried out with different thermocouple materials to eliminate this source of instrumental interference. Thus with increased reliability greater weight can be given to the observed peaks with a view to detailed explanation.

(2) Investigation of the transformation from petalite to high-spodumene for Industrial Chemistry Division showed a large endothermic reaction commencing around 1,000°C, and peaking at 1,150°C. This was associated with a slightly smaller exotherm at 1,200°C. A thermogram of the transformation of low to high spodumene showed an endotherm commencing at 930°C. peaking at 1,050°C. with no such associated exotherm, but base-line shifts were evident, caused by physical expansion in transforming from low spodumene to the less dense high spodumene. The thermograms are reproduced in Figure 9.

X-ray powder patterns of petalite product quenched at 1,150°C. and of petalite product after heating to 1,250°C. indicated that two forms of high spodumene were produced by these treatments. The diffraction patterns indicate that the first product, formed at the lower temperature, possesses higher symmetry than the second, which closely resembles the pattern of high spodumene formed from low spodumene. Further work is being done on the nature of these forms of high spodumene.

X-ray Diffraction.

An X-ray powder diffraction camera of 11.5cm. diameter has been recently acquired. The greater dispersion and accuracy available with this diameter, compared with the 5.75 cm. camera used for routine identification, is valuable in obtaining diffraction patterns of new mineral varieties for the purpose of determining unit cell dimensions, and for differentiating between structurally similar minerals. Such new varieties as are being studied are perite ($PbBiO_2Cl$), russellite ($(Bi_2W)O_6$), and a mineral of as yet unknown composition from Mogumber, Western Australia. Perite has been referred to in the report of the Mineral Division.

Some examples of the type of mineral identification by X-ray diffraction carried out by the Physicist and Mineral Division Mineralogists are given below.

(1) A mineral specimen from Kitchener Mine, Bamboo Creek, had been identified in 1929 as a sulphide of lead and bismuth. Since X-ray powder work on the mixed lead bismuth sulphides lillianite, goongarrite, and beegerite reported by Berry and Thompson in "X-ray Powder Data for Ore Minerals" (Geol. Soc. Am) had shown these to be mixtures of cosalite, galena, matildite and galenobismutite, the Bamboo Creek specimen was re-examined and shown to be a mixture of galena and tetrahedrite.

(2) A sample from an undisclosed locality was shown to contain romeite and its alteration products valentinite and cervantite.

The essentially calcium pyro-antimonate mineral romeite is iso-structural with West Australian microlite, which is a calcium tantalate and does not conform with the A.S.T.M. X-ray Powder Data File card for microlite. The differences between romeite and microlite patterns appear principally in the back reflection region with copper radiation; patterns taken with iron radiation can be distinguished only with difficulty.

(3) A series of bore cores through a manganese deposit was received from the Geological Survey. These were identified largely by X-ray diffraction methods to be mixtures of braunite, pyrolusite, cryptomelane and chalcopyrite.

(4) Two samples from the Engineering Chemistry Division evidenced the production of artificial minerals. One was a reduced manganese ore, and was shown to contain MnO, the artificial equivalent of the mineral manganosite. The other, also a manganese oxide, was identified as mangano-manganic oxide Mn_3O_4 being equivalent to the natural mineral hausmannite.

(5) In December, 1963, an article (Canadian Mineralogist 7(3), 400, 1963) was received describing a new monoclinic tantalite mineral, wodginite, discovered by the Canadian Mines Department.

Although the mineral was first recognised in 1961 from Bernic Lake, Manitoba it was named Wodginite in recognition of E. S. Simpson's identical specimen found in 1909 at Wodgina W.A. and in the absence of X-ray diffraction methods called ixiolite.

Using the new large diameter X-ray powder camera, ixiolite and tantalite samples from the laboratory collection were re-examined. The original "ixiolite" from Wodgina and an "ixiolite" from Tabba Tabba were proven to be wodginite.

Re-examination of old X-ray diffraction patterns showed a further occurrence of wodginite in a heavy concentrate from Marble Bar prophetically reported in 1958 as "monoclinic columbite-tantalite", but unpublished as such by these laboratories.

An interesting specimen of tin-bearing "tantalite" from Tabba Tabba was proven to be a typical ixiolite using the new X-ray data of the article.

(6) Two soil samples from ten miles south of Coorow were examined by X-ray diffraction and differential thermal analysis. The first gave a diffraction pattern resembling sepiolite, a fibrous magnesium silicate. A differential thermogram confirmed that the mineral was in fact exylotile, an iron-rich sepiolite. The second sample gave a diffraction pattern resembling a montmorillonoid and a sepiolite, and the thermogram indicated much sepiolite present. To this extent the second sample closely resembles the Marchagee bentonite examined previously. (Graham J: J. Roy. Soc. W.A. 37, 91, 1952.)

This bentonite, reportedly a saponite, demonstrates a capacity to rehydrate after heating which warrants study, and further separation is being carried out for this purpose.

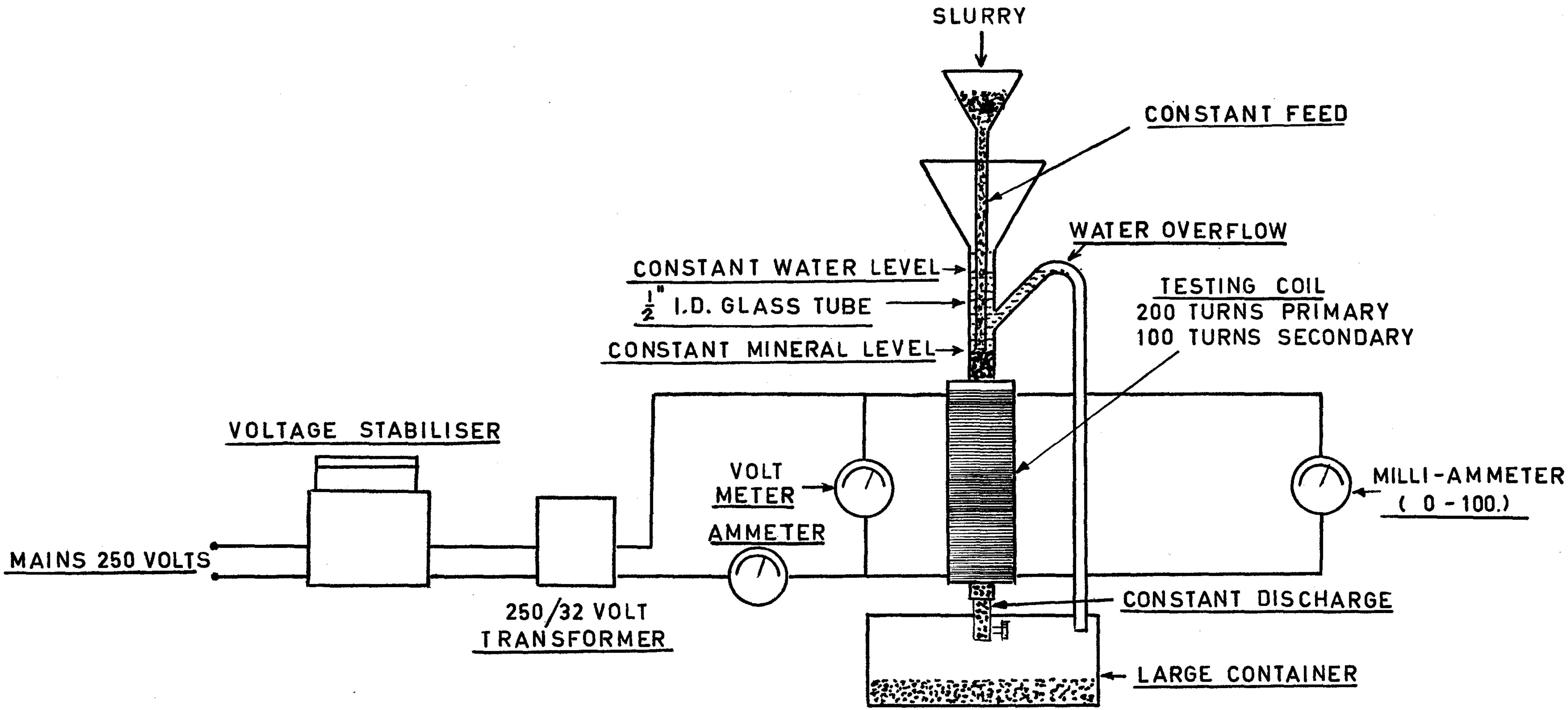

FIG.1. APPARATUS FOR DETERMINATION OF METALLIC IRON CONTENT

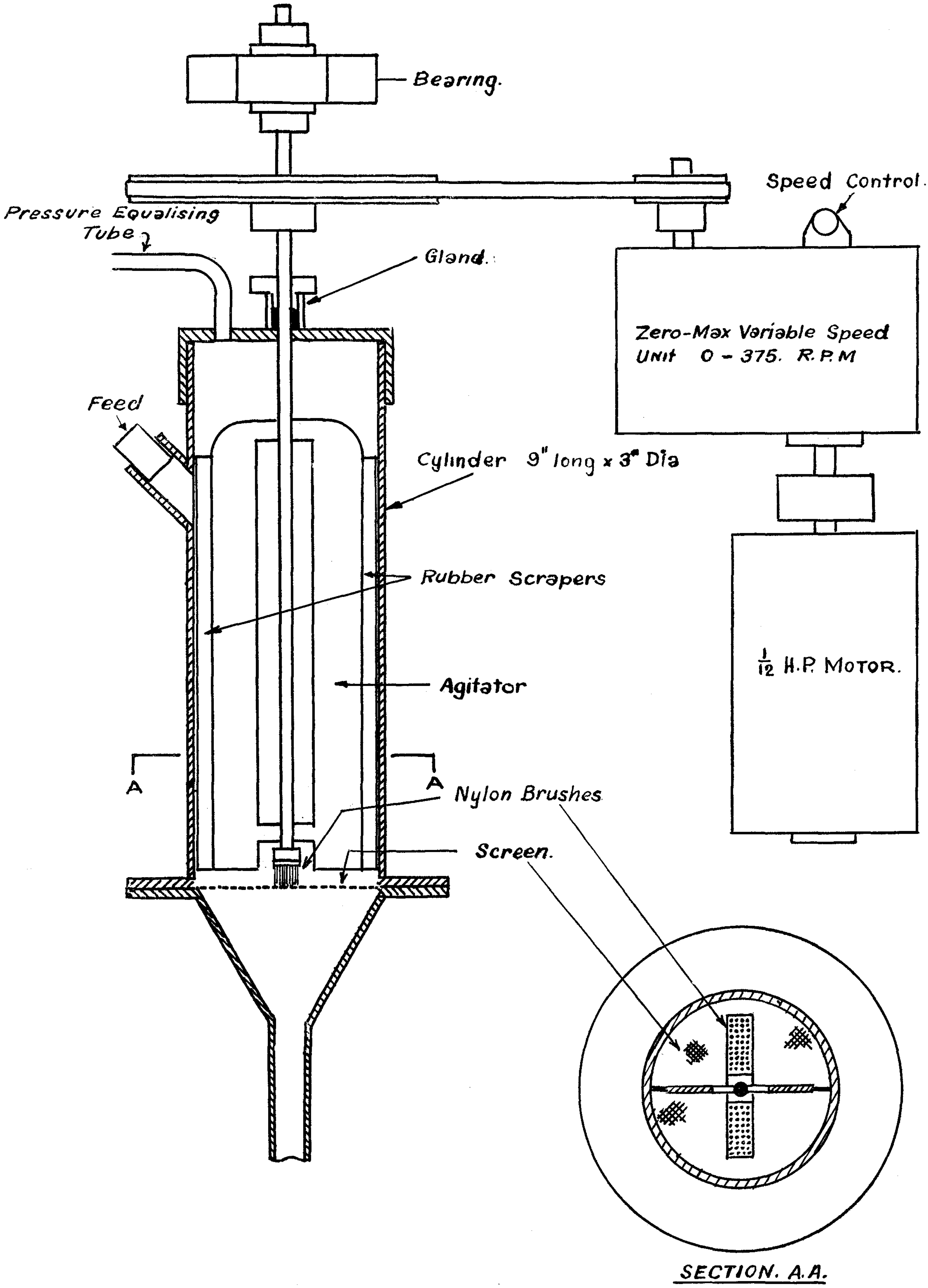

FIG. 2. BRUSHED-SCREEN FEEDER

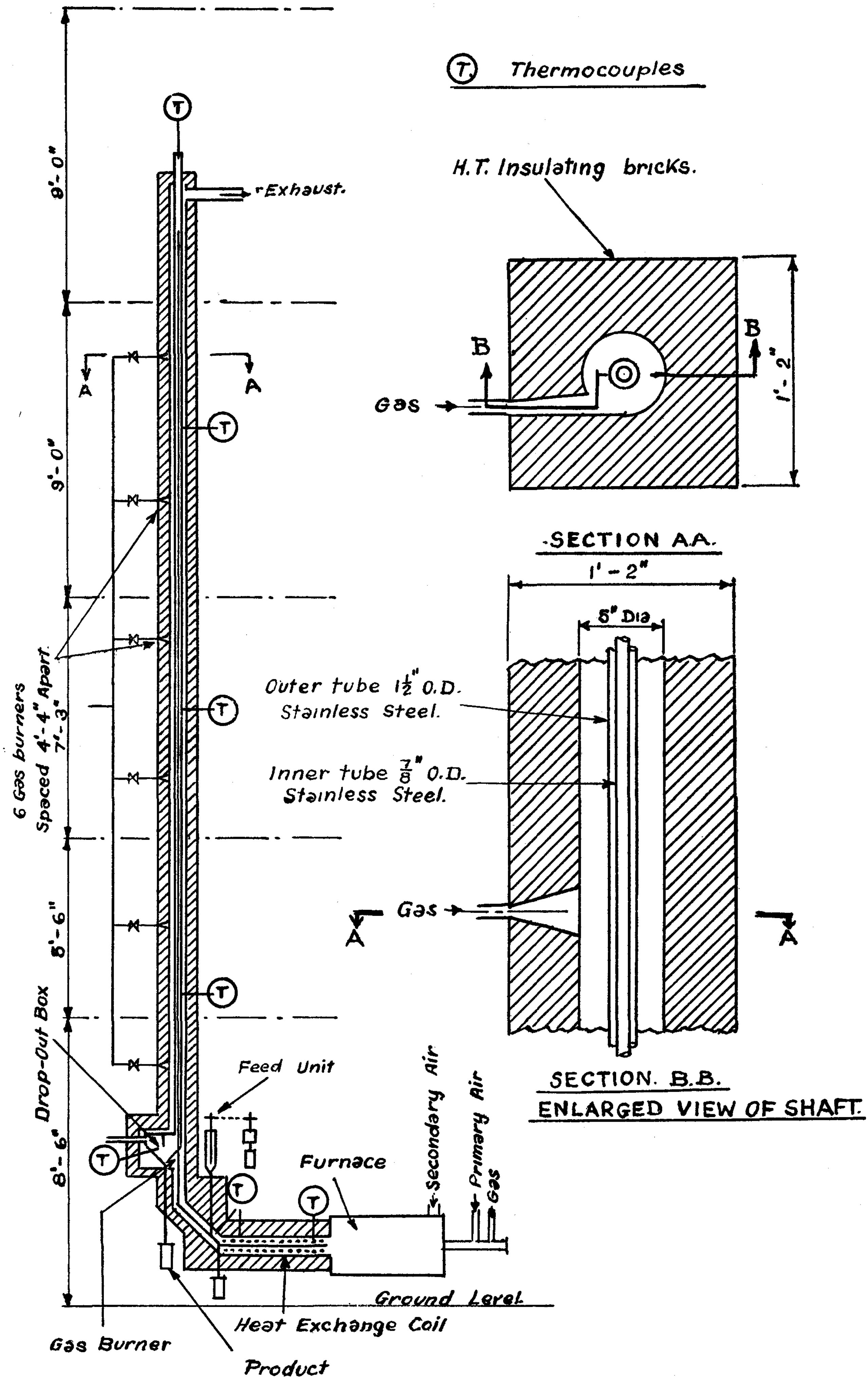

FIG 3 ENTRAINMENT REACTOR

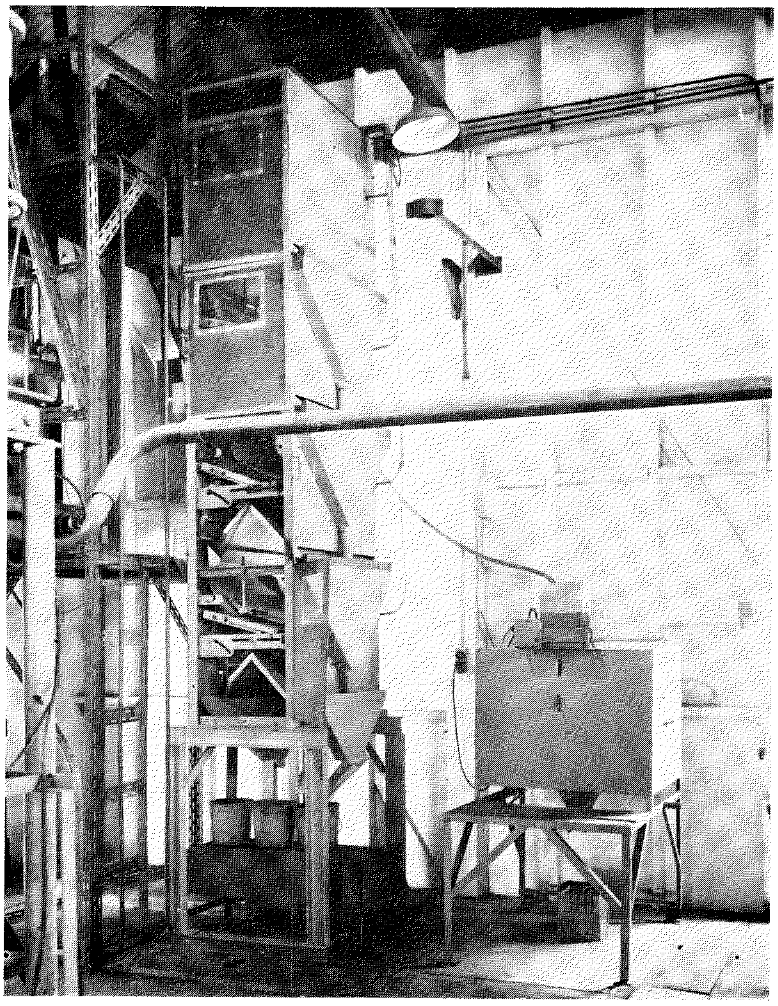

FIG 4

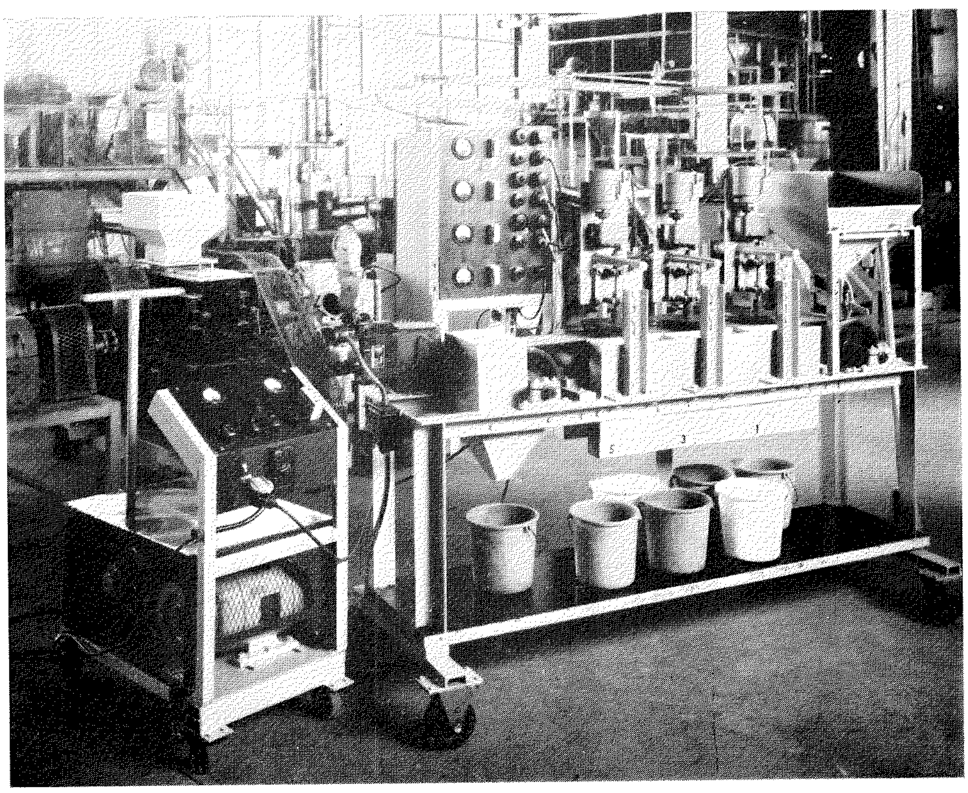

FIG 5

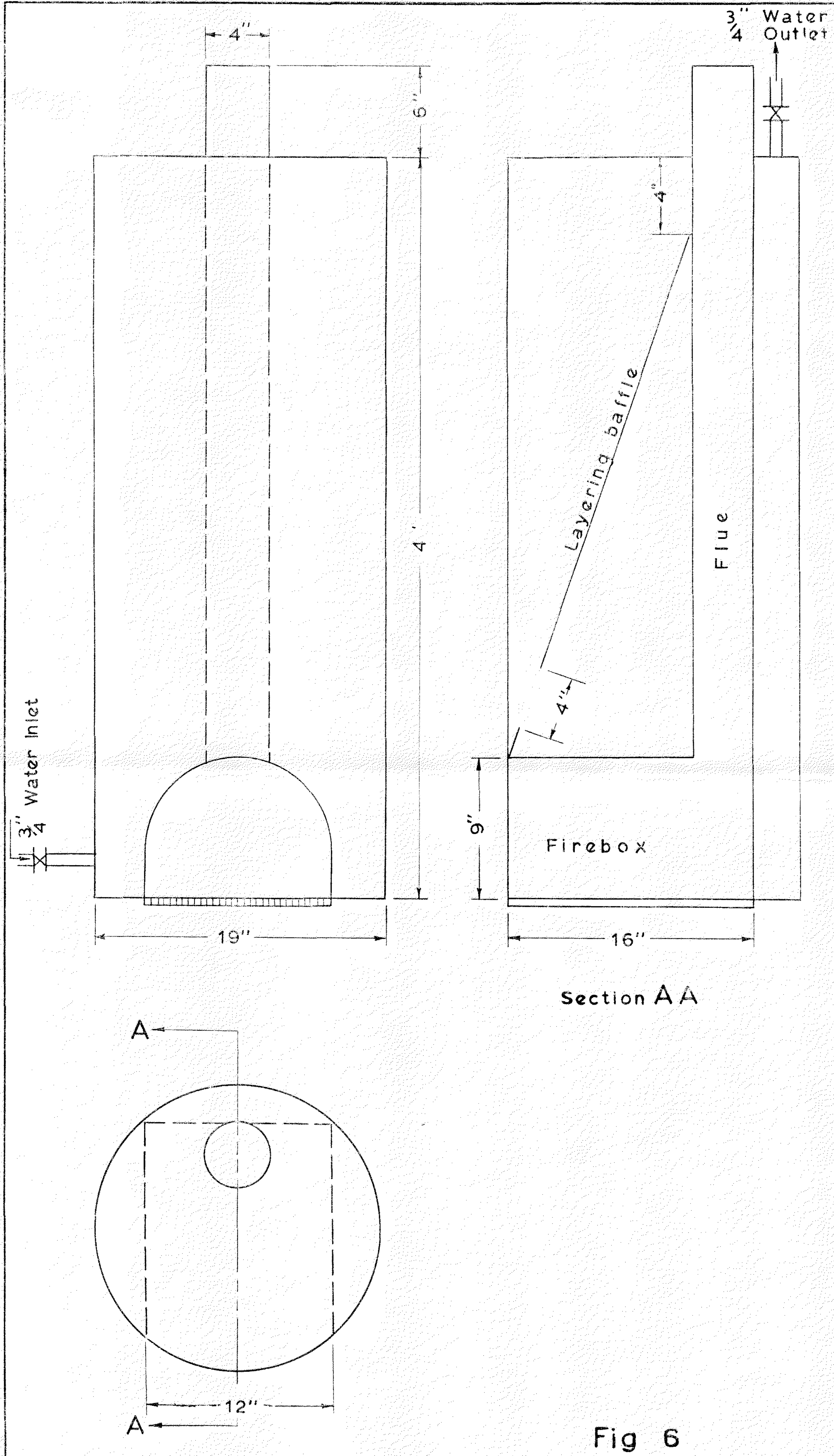

Fig 6

SOLID FUEL HOT WATER STORAGE HEATER

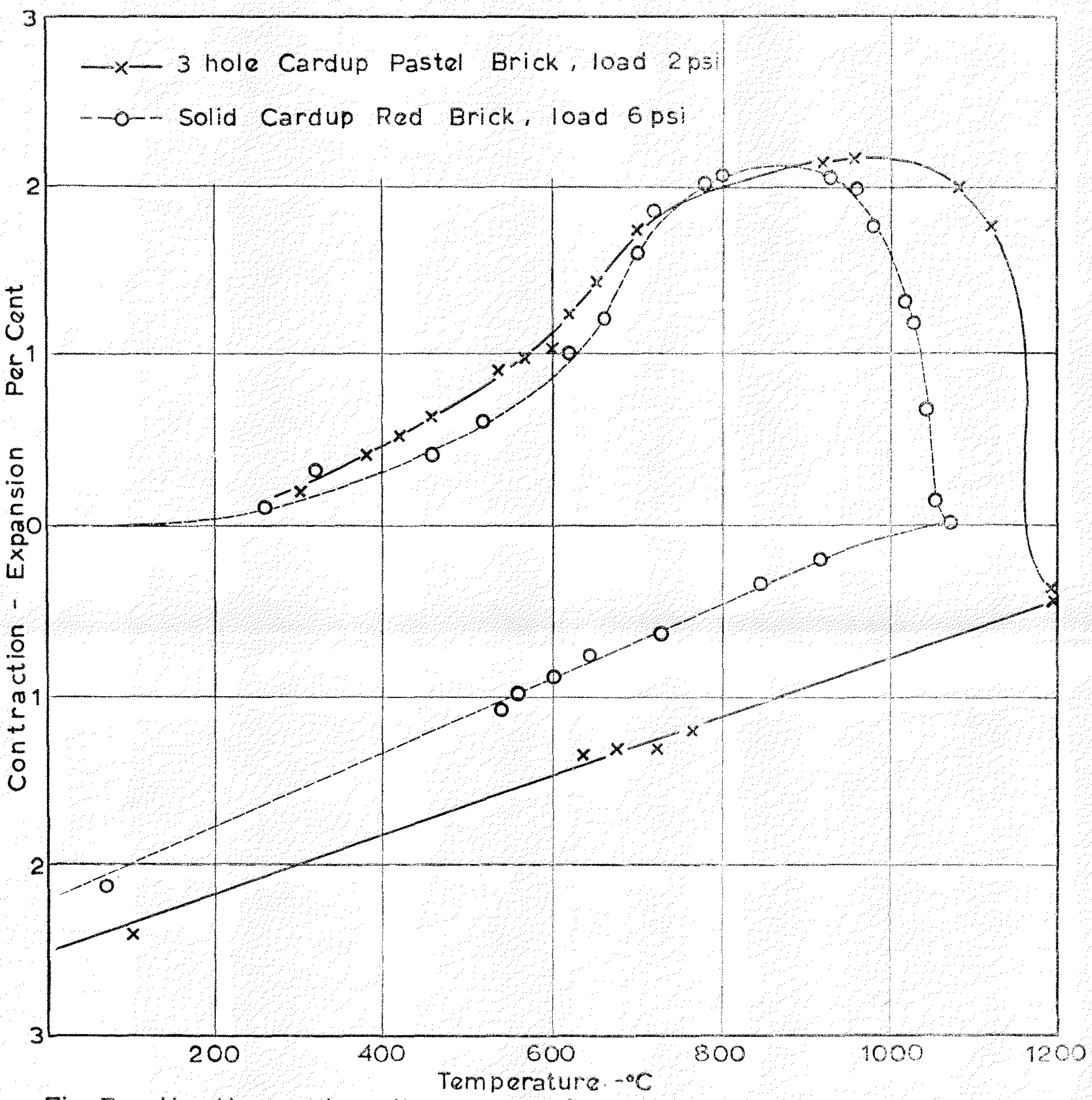

Fig 7 Heating and cooling curves for whole bricks.

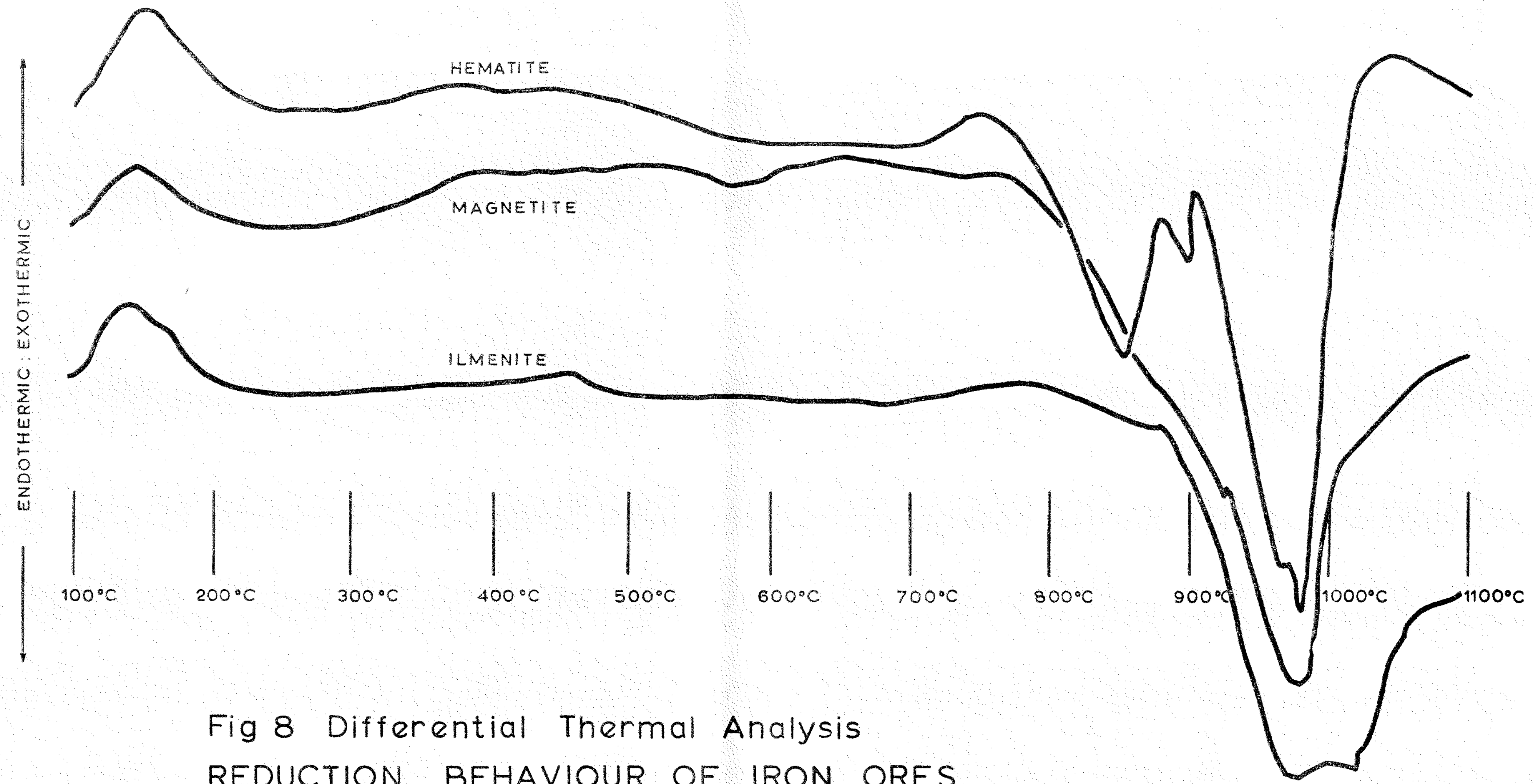

Fig 8 Differential Thermal Analysis
REDUCTION BEHAVIOUR OF IRON ORES

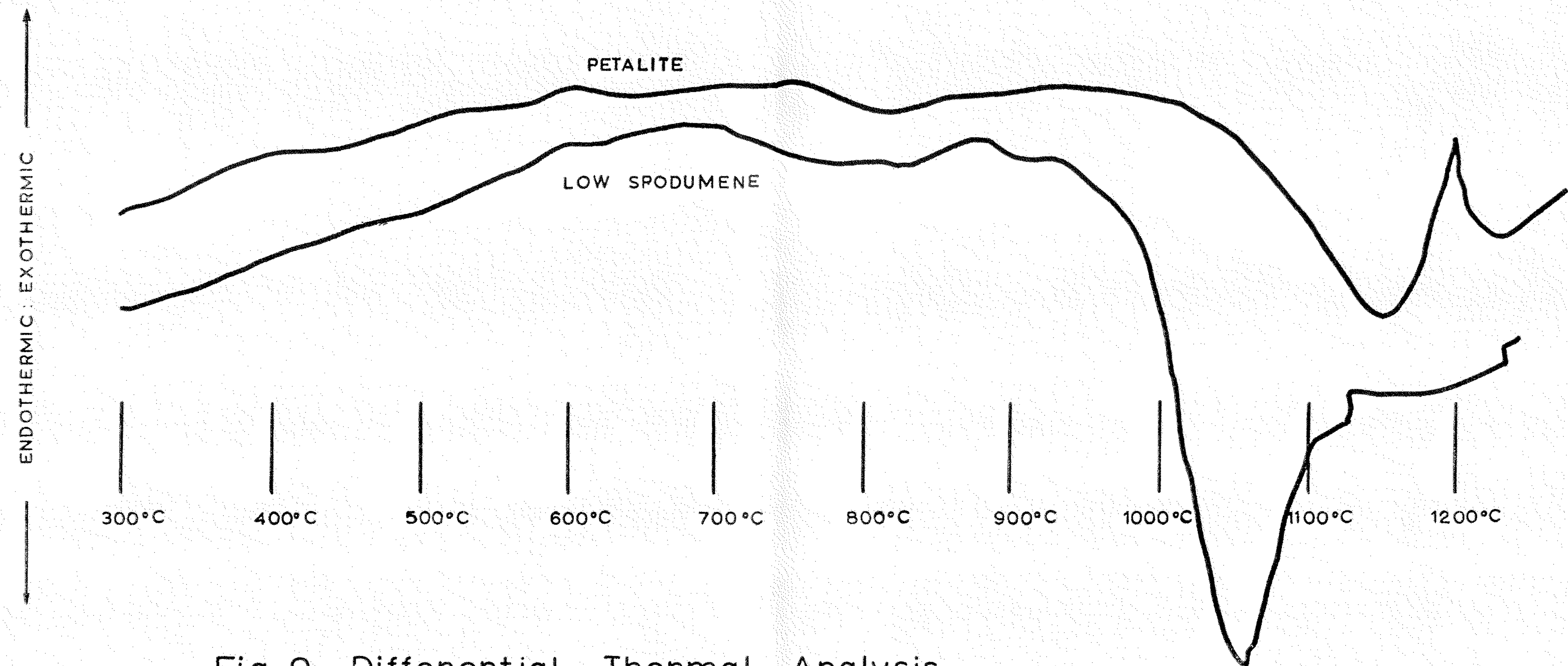

Fig 9 Differential Thermal Analysis

PETALITE — SPODUMENE TRANSFORMATION

DIVISION VIII

Annual Report of the Chief Inspector of Explosives for the Year 1964

The Under Secretary for Mines:

For information of the Hon. Minister for Mines I am pleased to report on the work of the Explosives Branch during 1964.

Staff.

Manned by two professional officers whose duties extend over the State and occasionally beyond, the Branch was hard put to cope with increasing work consequent upon new explosives technology and the establishment of explosives-consuming industrial undertakings. Further, dangerous goods regulation, when proclaimed, will open up another field of activity which could not be effectively pursued unless additional inspectors were appointed.

At Woodman's Point Explosives Reserve, Assistant Magazine Keeper W. P. Nissen resigned during August to enter employment by American Dupont explosives interests. After promotion of Senior Watchman C. Taylor to the vacancy, the staff was adjusted in proportion to the mounting explosives through-put by appointment of two watchmen.

Accommodation.

Apart from partitioning the inspector's desk from the general office, the two-room setup remained unchanged. Progress recorded at the reserve included complete renovation of three staff houses, gravelling and resurfacing of roads and approval for construction of a modern guard house and residence for the Magazine Keeper.

Importation of Explosives.

Those of Australian manufacture continued to reach the State by sea and rail, but the former approximate equality underwent slight displacement due to heavier railage of geoseismic and quarrying explosives to the coastal reserve. Though involving handling at the Kalgoorlie break of gauge, the system proved its worth by maintaining supplies for public works and the search for petroleum. The first shipment of explosives from U.S.A. arrived in such foul weather that following a small discharge at the jetty side the remainder had to be lightered and launched from the vessel at sheltered anchorage. A second consignment late in December was worked routinely.

Importation of Blasting Agent Components.

Little need be said of the oil because of its ready availability as diesel engine fuel. On the other hand, blasting agent grade ammonium nitrate prill rose from obscurity a few years ago to consumption of 2,500-3,000 tons during 1964. Supplies arrived from overseas in drums, supplemented by railage of 50 and 80 lb. polythene packs. The doubling of the former 75 ton limit on drummed nitrate at ordinary shipping berths proved its worth, against which the restriction to 25 tons in bags at isolated anchorage or berth came under strong criticism. It was held that as Woodman's Point Explosives Reserve jetty regularly unloaded 250 to 400 ton shipments of conventional high explosives, why should non-explosive prill be whittled to more or less token amounts? The only hope for relaxation lies with review by the Australian Port Authorities' Association Sub-Committee and acceptance of that body's recommendations by the Permanent Committee.

Importation of Nitro-carbo-nitrates.

Grouped in Class 3 Division 2 of the Classification, these products resemble blasting agents in their high ammonium nitrate content but differ fundamentally therefrom in that they are factory-made and marketed ready for use without further admixture or alteration in composition. Though claimed insensitive to bullet fire, impact and heat, they clearly fell within Australasian Explosives Departments' definitions and conceptions of explosives. Despite pressure from various quarters, this designation has continued to apply. In U.S.A. the N.C.Ns are not so defined, but existing legislation leaves no option for change in this country where, however, the matter is under close examination because of the expected importance of these explosives for works such as harbour deepening and off-shore geoseismology. Even as the situation now stands, no real hardship is anticipated. It is true that whilst N.C.N. movements are prohibited over non-isolated berths, as at Fremantle, the major usage will be in the N.W., where long jetties already built or intended should rationalise explosives traffic. So far, most N.C.N. has been unloaded at Woodman's Point Explosives Reserve for road conveyance to the major consumption centres hundreds or perhaps a thousand miles away.

Out-going Seaborne Explosives.

Small quantities were periodically launched to the British Phosphate Commission's vessels and several submarine geoseismic survey shooting boats received supplies across the Reserve jetty. The former carriage of explosives around northern Australia by iron ore vessels returning from N.S.W. to Cockatoo and Koolan Islands was superseded by shipment from B.H.P.'s rolling mills jetty at Kwinana.

Types of Authorised Explosives.

No compositions fundamentally different from established lines were encountered. Blasting explosives were authorised as tabulated—

Class 3, Division 1, Nitrocompound.
Toval.
Polar Rollex.

The following explosives, deemed covered by existing definitions, were also added to the list:—

Class 3, Division 1.—

Nobel Pistol Powders No. 2 and 3.
Revolver Powder No. 1.

Class 3, Division 2.—

Nobel Rifle Powders No. 0, 1, 2 and 3.

Class 6, Division 1—

Eley Kynoch Primers No. 175, 176, 177, 178.

Types of Blasting Agents.

Several makes of prilled ammonium nitrate, all of satisfactory oil absorptive capacity and well within the maximum permissible 0.05% organic matter content were available. Nitropril, an improved product from I.C.I's Botany plant in N.S.W., replaced the company's Nitrolite manufactured at Deer Park, Victoria.

Although no deviation from straight ammonium nitrate—fuel oil mixtures was recorded in industrial usage, the potentialities of certain additives were explained and demonstrated experimentally by Mr. R. W. Coxon, of Adelaide, at the A.I.M.M. Conference in Kalgoorlie last August. The compounds under trial, possessing in varying degree such properties as wetting, emulsifying, dispersing and detergency, are known as surface active agents or surfactants. Briefly stated, they lower surface tension in a liquid to give more intimate contact with other substances. Fuel oil emulsified with aid of a suitable surfactant should therefore associate closely with the prill to enhance sensitivity and effectiveness in the product. Surface shots appeared to bear out this assertion, though it was felt that for proper appraisal much plant-scale investigation remained.

The above developments, together with inquiries on slurry-type mixtures, have brought to light problems of classification and licensing. The greater sensitivity and more complicated composition of some such preparations may incline toward their designation as explosives rather than blasting agents. Yet provided the basic principle of compounding from non-explosive substances is maintained, the Branch will assume no suppressive attitude beyond that demanded by safety considerations.

Quality of Explosives.

The usual inspections, followed by stability tests and, where necessary chemical analysis and determinations of sensitivity and detonation velocity, established the year's explosives supplies as of satisfactory quality. Long sequences of high heat-tests, indicative of stability, were rarely broken by lower readings which, however, stood well above the danger point. Incipient nitroglycerin exudation in one type of American explosives did not intensify in respect to time.

Wetting in transit was the reason for rejecting seven cases of Toval and two of Gellex.

Quality of Blasting Agent Ammonium Nitrate.

The several makes of prill surpassed statutory compositional requirements, but sporadic instances of physical change were detected. Agglomeration, powdering and reversion to crystalline form, found both as patches or massively, resulted in quantities being rejected as unfit. Attempted reconditioning having failed, some of the deteriorated material was sold as fertilizer. Except in obvious instances of spoilage by ingression of moisture through defective packages, the trouble could not always be explained. One strongly suspected cause was that brought about by temperatures fluctuating around 90°F. It is noteworthy that mines, quarries and even small users of ammonium nitrate have taken measures to ensure cool storage, but the Branch's control cannot be exercised over railage and shipment outside the State.

Packaging Materials.

Except for cartridged explosives wrappings, paper has almost vanished from the scene. The outer fibreboard container with inner protection by polyethylene liners or bags was the generally used form of package. Ammonium nitrate reached here in drums usually of good quality but still in a few instances corroded, and occasional leakage from the 50 and 80 lb. plastic bag packs occurred.

Government Explosives Reserves.

Intended works at Geraldton and heavy industry to the north brought forth many inquiries as to explosives storage. The Geraldton situation appeared to be in hand because of a recently gazetted 40 acre block, and steps were taken to ensure adaquate provision at Port Hedland. Elsewhere in the north at some ports and inland localities of high potential importance, explosives reserves were either non-existent or too small for expected future requirements. It was therefore strongly recommended that in the siting of new mining towns and development of present or projected ports, at least 50 acres of suitably isolated land be ear-marked for explosives reserves.

Even at Woodman's Point the construction of three additional magazines for American Dupont explosives cast some doubt as to the location of additional buildings if required.

Magazines.

Those just mentioned incorporated many improvements on the older magazines, including access on opposite walls so that rail and road explosives movements might take place simultaneously. Magazine licencees in general have responded well to the Branch's drive for greater security and safety.

A prefabricated magazine capable of erection or dismantling in the field was inspected at a Perth factory. Advantages claimed included ready portability in collapsed form; a large truck or trailer could transport the constructional units for up to three such buildings, depending on size. Some demand may be expected both for general use and explosives storage in remote districts under industrial development.

Intra-State Railage of Prilled A.N.

Negotiations with the W.A.G.R. Commission at last resulted in acceptance of blasting-agent grade ammonium nitrate for conveyance at lower rates than those applicable to explosives. Quite understandably, the Commission sought unequivocal proof of the products' inexplosibility, and this was furnished on the basis of experimental work and chemical analysis. Coincidentally with the reduced freight, the practice of railing nominal amounts of bagged A.N. wrapped parcel-wise in tarpaulins was disallowed. This resulted in hardship to the small user, who in effect was faced with additional costs of encasing supplies in drums or portable magazines. Representations for reinstatement were unsuccessful, but the matter will not be dropped.

Conferences.

Mr. G. A. Greaves attended a meeting of the Australian Port Authorities' Sub-Committee in Sydney during October. The writer was present at several lectures and demonstrations on explosives technology during the A.I.M.M. Conference sessions in Kalgoorlie.

Explosives and Dangerous Goods Act, 1961.

In its application to explosives, blasting agents and fireworks the new legislation worked smoothly. A few small amendments were required. The more formidable task of preparing dangerous goods regulations neared completion, and gazettal may be expected about mid-1965.

Fireworks, Shopgoods Class.

Another quiet season commendably low in personal accident or incidence of inferior fireworks was recorded. The usual inspections of all lines on arrival served to establish compliance with State requirements. One Japanese firework intended to take off from the ground was banned because of erratic flight and the use of a metal propeller in its construction.

As a precaution against borers, a Commonwealth Quarantine regulation promulgated during the year insisted on fumigation of fireworks containing bamboo, cotton, seeds etc. in their construction or composition. Any such findings during inspection were therefore reported, the cases removed for treatment and, if otherwise acceptable, were released in the customary manner.

Pyrotechnic Mixtures.

Due to delayed ignition of a home-made composition, a Leederville youth sustained first-degree burns on his face, chest and right arm. No prosecution for illegal manufacture was instituted because the offender, aware of dangers besetting such amateur pursuits, was actually endeavouring to destroy the composition when the accident occurred.

Display Fireworks.

Several permits were issued both for professional displays and communal "bonfire nights" at which supervision was exercised and the fire hazard borne in mind. This type of celebration had much to commend it by comparison with the sometimes indiscriminate and uninhibited use of fireworks in backyards.

Submarine Blasting.

Offshore geoseismic surveys, harbor deepening and pile holeing for jetty construction might be expected seriously to deplete aquatic life. At the behest of the Fisheries Department, the Branch made some preliminary investigations, directed mainly to familiarisation with literature on the subject, about which little local information was available. Californian experience showed that depopulation may follow continued blasting, but the fish eventually returned. Crayfish and crustaceans generally, owing to their protective carapaces, were believed more resistant to percussion than vertebrates.

No means for conserving fish life in vicinity of blasting could be suggested. The well-known reduction in transmitted vibration by firing multiple charges at millisecond-delay intervals might be inapplicable to the works under discussion. In short, it seemed that destruction of marine life in varying degree must be regarded as a concomitant of industrial undertakings involving submarine blasting.

Conclusion.

Each member of my staff discharged his duties creditably during one of the busiest years on record. Particularly to Mr. G. A. Greaves, Inspector of Explosives, is gratitude expressed for fundamental work on the legislative control side and in so many other directions. The relationships with departmental colleagues and the explosives and dangerous goods trade have continued at high level.

F. F. ALLSOP,
Chief Inspector of Explosives.

DIVISION IX

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Report of Chairman, Miners' Phthisis Board and Superintendent Mine Workers' Relief Act, 1964

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Under Secretary for Mines:

I submit for the information of the Honourable Minister for Mines, my report on this Branch of the Mines Department for the year 1964.

General.

The State Public Health Department, under arrangements made with this Department, continued the periodical examination of mine workers, the work being carried on throughout the year at the State X-ray Laboratory, Kalgoorlie, and a mobile x-ray unit visited the North Coolgardie, Mt. Margaret, Murchison, Peak Hill, Pilbara, West Pilbara, Dundas, Yilgarn and Phillips River Goldfields and the Northampton and South West Mineral Fields.

Mine Workers' Relief Act.

Total Examinations.—The examinations under the Mine Workers' Relief Act during the year, totalled 4,155 as compared with 5,498 for the previous year, a decrease of 1,343. The results of the examinations are as follows:—

Normal	3,484
Silicosis early previously normal	64
Silicosis early previously silicosis early	561
Silicosis advanced previously normal	Nil.
Silicosis advanced previously silicosis early	9
Silicosis advanced previously solicosis advanced	1
Silico-tuberculosis previously normal	Nil.
Silico-tuberculosis previously silicosis early	1
Silico-tuberculosis previously silicosis advanced	Nil.
Tuberculosis	2
Asbestosis early previously normal	13
Asbestosis early previously asbestosis early	17
Asbestosis advanced previously normal	Nil.
Asbestosis advanced previously asbestosis early	2
Asbestosis advanced previously asbestosis advanced	Nil.
Asbestosis plus tuberculosis previously normal	Nil.
Asbestosis plus tuberculosis previously asbestosis	1
Total	4,155

These 1964 figures together with the figures for the previous years, are shown in the Table annexed hereto. Graphs are also attached illustrating the trend of examinations since 1940.

Analyses of Examinations.—In explanation of figures, I desire to make the following comments:—

Normal, Etc.—These numbered 3,484 or 83.85 per cent. of the men examined and include men having first class lives or suffering from fibrosis only. The figures for the previous year being 4,795 or 87.21 per cent.

Early Silicosis.—These numbered 625, of which 64 were new cases and 561 had been previously reported, the figures for 1963 being 188 and 451, respectively. Early silicotics represent 15.04 per cent. of the men examined, the percentage for the previous year being 11.62 per cent.

Advanced Silicosis.—There were 10 cases reported of which nine advanced from early silicosis during the year and one case had previously been reported. Advanced silicotics represent 0.24 per cent of the men examined, the percentage for the previous year being 0.40 per cent.

Silicosis Plus Tuberculosis.—One case was reported compared with 13 in 1963.

Tuberculosis Only.—Two cases were reported compared with three in 1963.

Asbestosis.—Two cases of advanced asbestosis, 30 cases of early asbestosis and one case of asbestosis plus tuberculosis were reported. Of the early cases 13 were new and 17 had been previously reported. Cases of asbestosis represented 0.80 per cent. of the total examinations while in 1963 the percentage was 0.47 per cent.

Mines Regulation Act.

Total Examinations.—Examinations under the Mines Regulation Act totalled 1,779. These were in addition to the 4,155 under the Mine Workers' Relief Act. There was a decrease of 227 examinations under this Act in 1964 as compared with those in 1963. Of the total of 1,779 men examined, 1,524 were new applicants and 255 were re-examinees.

Analyses of Examinations.—Particulars of examinations are as follows.—

New Applicants.

Normal	1,513
Silicosis early	3
Silicosis advanced	1
Other conditions	7
Total	1,524

Re-examinees.

Normal	243
Early silicosis	9
Other conditions	3
Total	255

These men had been previously examined and some were in the industry prior to this examination.

Health Certificates Issued to New Applicants and Re-Examinees.

The following health certificates were issued under the Mines Regulation Act:—

Initial Certificates (Form 2)	1,755
Temporary Rejection Certificate (Form 3)	1
Rejection Certificates (Form 4)	11
Re-admission Certificates (Form 5)	4
Special Certificates (Form 9)	2
No certificate issued	6
Total	1,779

The percentage of men of normal health (Initial Certificates) to the number examined was 92.47% compared with 97.11% in 1963.

Miner's Phthisis Act.

The amount of compensation paid during the year was £8,832 12s. 8d. compared with £9,597 1s. 8d. for the previous year.

The number of beneficiaries under the Act as on the 31st December, 1964, was 77, being 6 ex-miners and 71 widows.

Administrative.

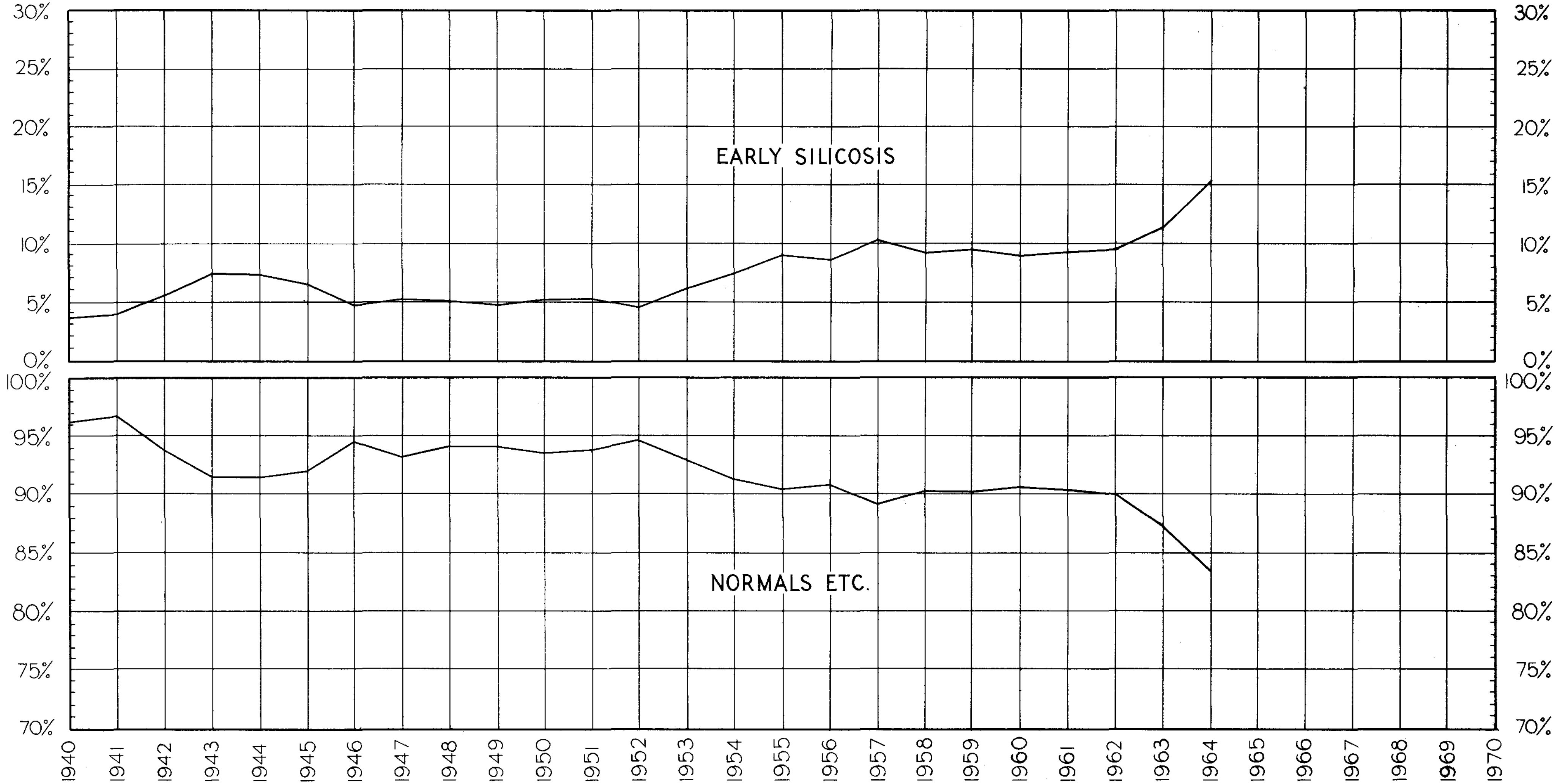
During the year the Mine Workers' Relief Act was amended to provide Section 56A benefits to service pensioners and to widows whose husband immediately prior to his death was qualified for such benefits save that he was receiving worker's compensation payments. Also the statutory authority for the payment of compensation to diseased mine workers was removed from the Mine Workers' Relief Act and re-enacted in the Workers' Compensation Act. A number of other minor amendments were also made.

W. Y. R. GANNON,
Superintendent Mine Workers' Relief Act
and Chairman Miner's Phthisis Board.

PERIODICAL EXAMINATION OF MINE WORKERS

GRAPH Nº 1

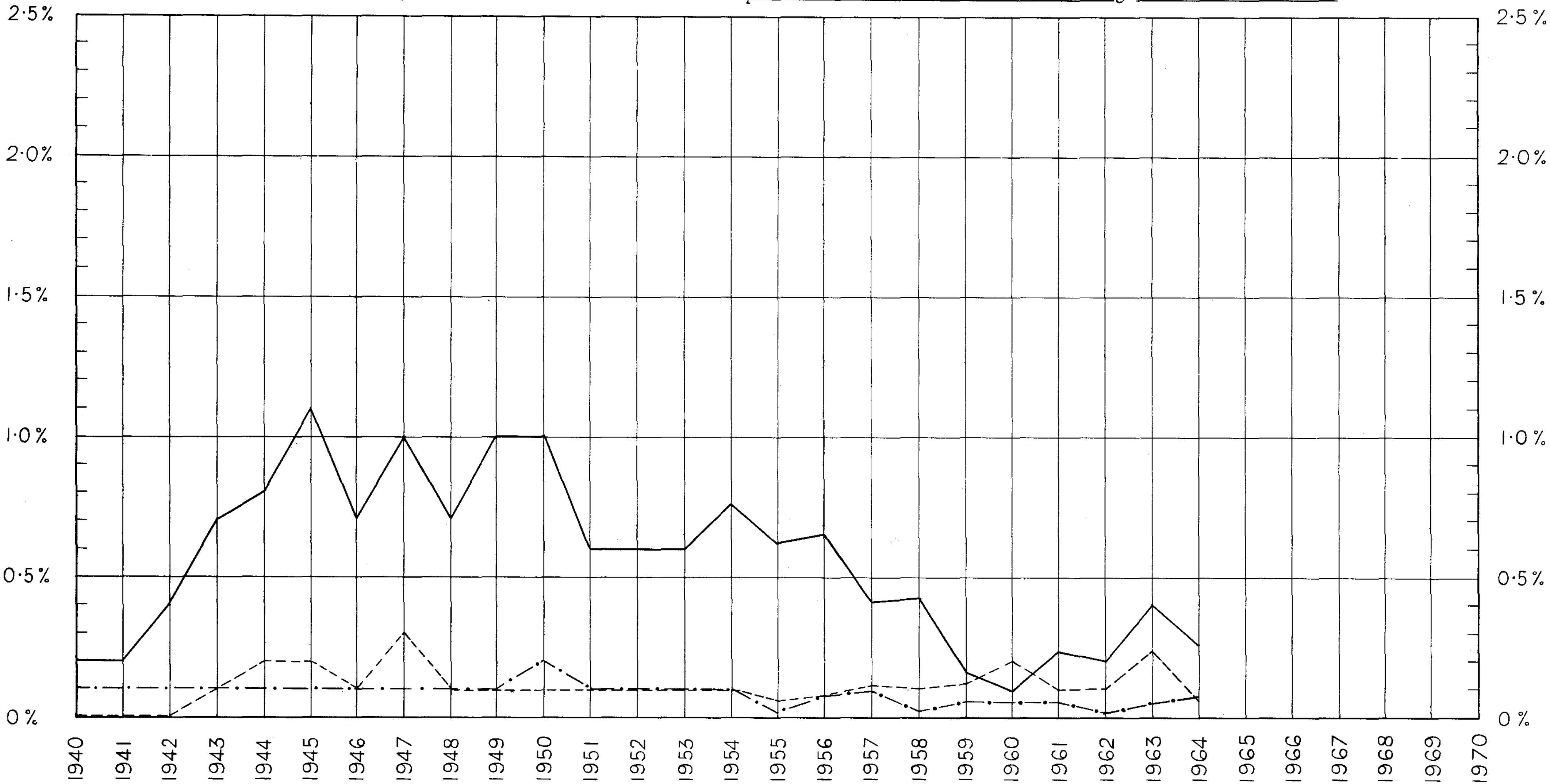
Showing Percentages of Normals and Early Silicotics from 1940 onwards



PERIODICAL EXAMINATION OF MINE WORKERS

GRAPH Nº 2

Showing Percentages of Silicosis Advanced, Silicosis plus Tuberculosis and Tuberculosis only, from 1940 onwards



Silicosis Advanced ———— *Silicosis Plus Tuberculosis* – – – – – *Tuberculosis Only* —·—·—·—

TABLE SHOWING RESULTS OF PERIODICAL EXAMINATION OF MINE WORKERS FROM INCEPTION OF EXAMINATIONS (1925).

	Normal		Silicosis Early				Silicosis Advanced					Silicosis plus Tuberculosis					Tuberculosis Only		Asbestosis									
Year	Total	Per Cent.	Previously reported as Normal etc.	Previously reported as Silicosis Early	Total	Per Cent.	Previously reported as Normal etc.	Previously reported as Silicosis Early	Previously reported as Silicosis Advanced	Total	Per Cent.	Previously reported as Normal etc.	Previously reported as Silicosis Early	Previously reported as Silicosis Advanced	Total	Per Cent.	Total	Per Cent.	Asbestosis early previously normal	Asbestosis early previously asbestosis early	Asbestosis advanced previously normal	Asbestosis advanced previously asbestosis early	Asbestosis advanced previously asbestosis advanced	Asbestosis plus tuberculosis previously normal	Asbestosis plus tuberculosis previously asbestosis	Total	Per Cent.	Total
1925 } 1926 }	3,239	80·5	....	....	459	11·4	....	....	....	183	4·5	....	....	....	131	3·3	11	0·3	....	....	....	....	....	....	....	....	....	4,023
1927	3,116	83·6	33	348	381	10·2	8	....	85	93	2·5	39	27	62	128	3·4	10	0·3	....	....	....	....	....	....	....	....	....	3,728
1928	2,977	85·5	59	303	362	10·4	3	16	79	98	2·8	18	14	10	42	1·2	4	0·1	....	....	....	....	....	....	....	....	....	3,483
1929	2,120	81·9	102	224	326	12·6	....	34	60	94	3·6	8	14	19	41	1·6	7	0·3	....	....	....	....	....	....	....	....	....	2,588
1930	2,785	81·9	136	247	383	11·3	2	22	43	67	2·0	8	60	46	114	3·3	50	1·5	....	....	....	....	....	....	....	....	....	3,399
1931	2,530	84·0	94	252	346	11·5	....	18	35	53	1·8	4	35	19	58	1·9	25	·8	....	....	....	....	....	....	....	....	....	3,012
1932	3,835	89·5	35	338	373	8·7	....	6	47	53	1·2	3	9	4	16	·4	8	·2	....	....	....	....	....	....	....	....	....	4,285
1933	2,920	86·5	57	322	379	11·2	1	15	44	60	1·8	2	9	4	15	·4	3	·1	....	....	....	....	....	....	....	....	....	3,377
1934	5,140	92·4	54	315	369	6·6	1	24	12	37	·7	6	6	....	12	·2	5	·1	....	....	....	....	....	....	....	....	....	5,563
1935	4,437	92·3	35	303	338	7·0	....	24	2	26	·6	....	5	....	5	·1	2	·0	....	....	....	....	....	....	....	....	....	4,808
1936	6,972	94·7	29	323	352	4·8	1	15	4	20	·3	3	8	....	11	·1	8	·1	....	....	....	....	....	....	....	....	....	7,363
1937	7,487	95·4	15	319	334	4·3	....	14	4	18	·2	1	10	....	11	·1	2	·0	....	....	....	....	....	....	....	....	....	7,852
1938	6,833	95·7	13	266	279	3·9	....	15	2	17	·2	1	8	....	9	·1	3	·0	....	....	....	....	....	....	....	....	....	7,141
1939	6,670	95·6	18	264	282	4·0	....	7	3	10	·1	1	9	1	11	·2	2	·0	....	....	....	....	....	....	....	....	....	6,975
1940	7,023	96·2	12	245	257	3·5	....	10	1	11	·2	....	4	....	4	·0	4	·0	....	....	....	....	....	....	....	....	....	7,299
1941	6,840	95·8	32	248	280	3·9	....	11	3	14	·2	....	....	....	....	....	7	·1	....	....	....	....	....	....	....	....	....	7,141
1942	5,469	93·9	61	264	325	5·6	....	20	5	25	·4	....	2	....	2	·0	3	·1	....	....	....	....	....	....	....	....	....	5,824
1943	3,932	91·5	63	262	325	7·6	....	25	7	32	·7	....	5	....	5	·1	4	·1	....	....	....	....	....	....	....	....	....	4,298
1944	4,079	91·5	70	270	340	7·5	....	21	14	35	·8	1	7	....	8	·2	6	·1	....	....	....	....	....	....	....	....	....	4,468
1945	3,071	92·1	54	166	220	6·6	....	26	10	36	1·1	3	2	....	5	·2	2	·1	....	....	....	....	....	....	....	....	....	3,334
1946	5,294	94·4	89	172	361	4·7	1	36	2	39	·7	3	1	2	6	·1	6	·1	....	....	....	....	....	....	....	....	....	5,606
1947	6,021	93·3	101	237	338	5·2	....	49	9	58	1·0	13	11	1	25	·3	8	·1	....	....	....	....	....	....	....	....	....	6,450
1948	4,827	94·0	24	239	263	5·1	....	18	17	35	·7	1	3	....	4	·1	5	·1	....	....	....	....	....	....	....	....	....	5,134
1949	5,162	94·0	24	239	263	4·8	....	20	31	51	1·0	3	2	1	6	·1	7	·1	....	....	....	....	....	....	....	....	....	5,489
1950	5,077	93·6	14	269	283	5·2	....	14	41	55	1·0	....	1	2	3	·1	8	·2	....	....	....	....	....	....	....	....	....	5,426
1951	4,642	93·9	13	248	261	5·3	....	9	20	29	·6	....	4	2	6	·1	4	·1	....	....	....	....	....	....	....	....	....	4,942
1952	5,073	94·6	8	234	242	4·5	....	4	31	35	·6	....	2	....	2	·1	7	·1	....	....	....	....	....	....	....	....	....	5,359
1953	4,474	93·03	74	225	299	6·22	....	8	24	32	·6	....	2	....	2	·1	2	·1	....	....	....	....	....	....	....	....	....	4,809
1954	5,142	91·33	154	275	429	7·62	....	22	21	43	·76	1	6	2	9	·1	7	·1	....	....	....	....	....	....	....	....	....	5,630
1955	4,559	90·40	63	386	449	8·90	....	9	22	31	·62	1	1	1	3	·06	1	·02	Segregation of asbestosis diagnoses commenced in 1959									5,043
1956	4,600	90·78	25	401	426	8·41	....	8	25	33	·65	1	3	....	4	·08	4	·08	....	....	....	....	....	....	....	....	....	5,067
1957	3,925	89·08	30	424	454	10·30	....	8	10	18	·41	1	4	....	5	·12	4	·09	....	....	....	....	....	....	....	....	....	4,406
1958	5,154	90·20	46	483	529	9·26	....	15	9	24	·42	....	6	....	6	·10	1	·02	....	....	....	....	....	....	....	....	....	5,714
1959	5,242	90·10	66	485	551	9·47	....	9	....	....	·15	1	5	1	7	·12	3	·05	6	....	....	....	....	....	....	6	....	5,818
1960	5,214	90·54	50	473	523	9·08	....	5	....	5	·09	2	9	....	11	·19	3	·05	2	....	....	....	....	1	....	3	....	5,759
1961	5,188	90·18	54	479	533	9·26	....	13	....	13	·23	2	3	....	5	·09	3	·05	5	5	....	1	....	....	....	11	·19	5,755
1962	5,183	89·98	50	499	549	9·53	1	10	....	11	·19	1	5	....	6	·10	1	·02	2	7	....	1	....	....	....	10	·18	5,760
1963	4,795	87·21	188	451	639	11·62	....	22	....	22	·40	7	6	....	13	·24	3	·05	10	11	....	4	....	1	....	26	·47	5,498
1964	3,484	83·85	64	561	625	15·04	....	9	1	10	·24	....	1	....	1	·02	2	·05	13	17	....	2	....	....	1	33	·80	4,155

DIVISION X

Report of the Chief Draftsman for the Year 1964

Under Secretary for Mines:

I have the honour to submit, for the information of the Hon. Minister for Mines, my report on the operation of the Survey and Mapping Branch, for the year ended 31st December, 1964.

Staff.

The staff of the Branch totals 40 officers, consisting of 4 females and 36 males.

Due to the keen interest in the mineral potential and iron ore resources of the State, the amount of work required to be performed by all sections increased considerably.

The officers, are to be commended on their excellent co-operation in coping with the added demand.

Cadets K. Woods and R. Stoelwinder became eligible for appointment as fully qualified draftsmen, while all cadets, in rotation, gained valuable practical field experience, from licensed surveyors and departmental geologists.

Close liaison was maintained with the Government Print and other Government Departments during the year.

Reports in summarised form, of the sections of the Branch are as follows:—

A. A. HALL,
Chief Draftsman.

Surveys.

Contract surveys to the value of £5,799 were carried out during the year by 7 Surveyors at the following centres:—

South West Mineral Field:
- Mt. Barker
- Kamballup
- Esperance
- Canning Mills

Kimberley Goldfield:
- Halls Creek
- Ruby Queen
- Grants Creek
- Golden Crown
- Mt. Angelo
- Mt. Dockrell

West Pilbara Goldfield:
- Wonmunna

Ashburton Goldfield:
- Warroora

Gascoyne Goldfield:
- Carnarvon

Coolgardie Goldfield:
- Coolgardie
- Bullabulling
- Tindals

East Coolgardie Goldfield:
- Belgravia
- Brown Hill
- Kalgoorlie

Murchison Goldfield:
- Boogardie
- Lennonville
- Day Dawn
- Cue
- Pinnacles
- Meekatharra
- Gabanintha
- Nanadie

East Murchison Goldfield:
- Agnew
- Goanna Patch

Pilbara Goldfield:
- Mt. Goldsworthy

Phillips River Goldfield:
- Ravensthorpe

Survey Examination.

Diagrams of surveys were drawn and examined. Original and duplicate plans were prepared on lease instruments and diagrams of surrender and resumption were prepared as required.

Geodetic.

Calculations for the laying down on the Transverse Mercator Projection of our Standard Plans, were carried out for the following sheets.

G50-2-146—
- Yinnietharra 80
- Yinnietharra 20-1
- Yinnietharra 20-2

G50-2-145—
- Lockier Range 80
- Lockier Range 20-12

F50-16-178—
- Pamelia 80

F50-14-113—
- Mangaroon 80

G50-6-176—
- Glenburgh 80

G50-8-267—
- Mt. Beasley 80
- Mt. Beasley 20-5
- Mt. Beasley 20-9
- Mt. Beasley 20-13

G50-8-277—
- Peak Hill 80
- Peak Hill 20-6
- Peak Hill 20-10
- Peak Hill 20-12

F50-3-10—
- Portree 80
- Portree 20-9

Mapping.

1. Two hundred and three technical plans were prepared and drawn for Geological Surveys together with 5,609 prints and duplicates from various originals.

Northampton, Nanson and Wokatherra of the 1 : 50,000 geological series in the vicinity of Northampton were published.

Dampier 1 : 250,000 geological map was printed and made available, while Mt. Bruce was completed and forwarded for publication.

Drafting work on maps in the same series was commenced on the following:—Pyramid, Widgiemooltha, Roy Hill, Newman and Roebourne.

A special project, the compilation of a new State base map for Geological and Departmental purposes was commenced on Albers Projection at a scale of 1 : 2,500,000.

2. Miscellaneous reproductions for Chemical Laboratories, Explosive and Inspection of Machinery Branches were carried out.

Certificates and time-tables, etc., were prepared for School of Mines, Kalgoorlie.

3. Dyeline prints and duplicates of all types produced during the year amounted to a total of 15,415 copies, representing an increase of 17 per cent. over the year 1963 and an increase of 95 per cent. over the previous two years.

The programme of re-drawing the 20 chains lithographic series was continued and the main Departmental mapping covered the following:—

(a) 1 : 50,000 Series published: Woodstock, Mungaroona Range, Mulga Downs and Joffre.

(b) Completed and awaiting publication: Mooratherra, White Springs, and Mt. Frederick. Eleven others are in various stages of progress.

Public Plans.

This section has felt the impact of the increased activity in mining for minerals and the search for oil, to a marked degree, as its function is to receive and process all applications for mining tenements and temporary reserves; to meet public enquiries and to keep up-to-date a set of plans for the same purpose.

During the year the following applications were received:—

Mining Tenements (Prospecting Areas, Claims, Leases, etc.	1,119
Temporary Reserves	407
Licenses to Prospect (Oil)	20
Permits to Explore (Oil)	12

In addition numerous plans were provided throughout the year for the general public and Outstation Mining Registrars.

Searches to determine land tenure and mineral ownership have been carried out and the search index system maintained.

MINING STATISTICS
to 31st December, 1964

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TABLE I.

PRODUCTION OF GOLD AND SILVER FROM ALL SOURCES, SHOWING IN FINE OUNCES THE OUTPUT AS REPORTED TO THE MINES DEPARTMENT DURING 1962, AND THE TOTAL PRODUCTION TO DATE.

(*Note.*—Lease numbers in brackets indicate that the holding was *voided* during the year.)

(*Note.*—* Denotes mainly derived from treatment of tailings. † Denotes mainly derived from Lead Ore. ‡ Denotes mainly derived from Copper Ore. § Concentrates. || Tantalum.

Mining Centre	Number of Lease	Registered Name of Company or Lease	Total for 1964					Total Production				
			Alluvial	Dollied and Specimens	Ore treated	Gold therefrom	Silver	Alluvial	Dollied and Specimens	Ore treated	Gold therefrom	Silver
			Fine ozs.	Fine ozs.	Tons (2,240 lb.)	Fine ozs.	Fine ozs.	Fine ozs.	Fine ozs.	Tons (2,240 lb.)	Fine ozs.	Fine ozs.
Kimberley Goldfield.												
Brockman	....	Voided Leases	....	....	....	....	....	....	....	1,545·75	1,455·34	....
		Sundry claims	....	....	....	....	....	7·62	7·62	2,484·00	1,871·92	....
Halls Creek	G.M.L. 124	New Golden Crown	....	....	....	....	....	....	....	120·00	21·64	....
		Voided leases	....	....	....	....	....	....	....	423·00	477·76	....
		Sundry claims	....	....	....	....	....	27·73	....	217·05	179·57	12·64
Mary	....	Voided leases	....	....	....	....	....	82·66	951·52	399·00	210·03	....
		Sundry claims	....	....	....	....	....	....	14·36	46·85	53·66	....
Mt. Dockrell	....	Voided leases	....	....	....	....	....	9·17	13·66	1,173·70	1,206·09	93·00
		Sundry claims	....	....	....	....	....	18·89	31·31	160·00	89·64	....
Panton	....	Voided leases	....	....	....	....	....	....	....	42·95	140·47	....
		Sundry claims	....	....	....	....	....	....	6·28	6·15	18·01	....
Ruby Creek	G.M.L. 97	Ruby Queen	....	....	60·00	15·42	....	....	....	3,129·25	1,746·47	2·14
		Voided leases	....	....	....	....	....	....	16·05	12,902·20	9,619·82	....
		Sundry claims	....	....	....	....	....	12·71	....	281·25	183·30	....
From Goldfield generally :—												
Sundry Claims			....	....	....	....	....	....	....	....	....	†20·98
Reported by Banks and Gold Dealers			....	....	....	....	....	8,920·90	1,975·55	·75	8·15	....
		Total	....	....	**60·00**	**15·42**	....	**9,079·68**	**3,016·35**	**22,931·90**	**17,281·87**	**128·76**
West Kimberley Goldfield.												
Napier Range	M.C. 29	Devonian Silver Lead Mine	....	....	....	....	†11,656·46	....	....	....	....	†25,231·75
From Goldfields generally :—												
Sundry Claims			....	....	....	....	....	....	13·76	1·00	2·49	....
Reported by Banks and Gold Dealers			....	....	....	....	....	1·30	10·92	....	....	....
		Total	....	....	....	....	**†11,656·46**	**1·30**	**24·68**	**1·00**	**2·49**	**†25,231·75**

Pilbara Goldfield.

MARBLE BAR DISTRICT.

Bamboo Creek	G.M.L. 1120	Bamboo Queen	....	....	....	....	....	....	....	88·50	30·99	·34
	1107	Bulletin	....	....	....	....	....	....	....	995·25	446·03	2·02
	1118	Kitchener	....	....	....	....	....	....	....	291·00	307·97	3·53
	1203	Mt. Prophecy	....	....	448·00	207·10	23·26	....	....	539·00	236·05	23·26
	1095, (1096), (1097)	Mt. Prophecy Leases	....	....	....	....	....	....	24·50	3,053·00	1,096·72	49·63
	817	Prince Charlie	....	....	206·50	54·14	12·71	....	3·68	9,582·25	6,424·62	294·00
	1072	Princess May	....	....	....	....	....	....	....	92·50	24·27	....
	924	True Blue	....	....	....	....	....	·62	....	4,671·25	114·64	·22
		Voided leases	....	....	....	....	....	13·54	568·41	49,263·85	55,709·29	8·97
		Sundry claims	....	....	....	....	....	8·97	307·83	5,208·85	3,034·45	7·21
Boodalyerrie	....	Voided leases	....	....	....	....	....	....	292·07	120·25	587·86	....
		Sundry claims	....	....	....	....	....	....	7·16	....	....	....
Braeside	....	Sundry claims	....	....	....	....	....	....	....	....	....	†25,853·75
Lalla Rookh	....	Voided leases	....	....	....	....	....	....	4·78	3,612·00	4,696·33	574·01
		Sundry claims	....	....	....	....	....	....	....	8,125·75	7,858·79	....
Marble Bar	930 (956)	Alexander leases	....	....	....	....	....	....	....	354·50	120·94	·81
	930	Alexander	....	....	....	....	....	....	....	640·00	114·59	....
	1094	Blue Bar	....	....	275·00	16·47	....	....	....	1,462·50	183·66	·48
	927, 934, 928	Halley's Comet Leases	....	....	....	....	....	....	....	6,360·00	6,390·33	680·36
	927, 934	Prior to transfer to present holders	....	....	....	....	....	....	....	355·00	1,002·94	....
	1121	Little Portree	....	....	....	....	....	....	....	103·00	66·88	6·93
		Voided leases	....	....	....	....	....	45·98	199·09	165,602·49	150,726·16	595·61
		Sundry claims	....	....	194·50	29·75	1·53	67·08	255·30	21,698·04	12,895·46	10·96
North Pole	1122, (1123), (1124)	Normay Leases	....	....	....	....	....	....	....	1,685·00	1,435·98	1,755·28
		Voided leases	....	....	....	....	....	....	....	4,339·00	1,930·51	260·08
		Sundry claims	....	....	....	....	....	....	....	669·75	298·62	15·82
North Shaw	....	Voided leases	....	....	....	....	....	7·53	....	1,072·45	996·29	....
		Sundry claims	125·55	....	....	....	·05	128·39	579·91	179·75	121·72	·05
Pilgangoora	1208	Birthday Gift	....	....	37·00	53·35	....	....	....	37·00	53·35	....
		Voided leases	....	....	....	....	....	16·65	....	2,279·00	407·57	....
		Sundry claims	....	....	30·00	23·33	·04	161·08	47·76	571·60	301·16	·04
Sharks	1082, etc.	Table Top Leases	....	....	....	....	....	....	....	1,082·75	594·97	17·28
		Voided leases	....	....	....	....	....	1·43	....	1,739·50	1,969·65	1·16
		Sundry claims	....	....	....	....	....	163·14	47·93	1,159·50	1,675·34	·97
Talga Talga	....	Voided leases	....	....	....	....	....	....	93·15	1,799·00	1,760·68	....
		Sundry claims	....	....	....	....	....	76·17	85·18	2,013·65	1,509·26	·70
Tambourah	....	Voided leases	....	....	....	....	....	....	73·90	1,603·50	1,886·22	....
		Sundry claims	....	....	....	....	....	89·52	294·75	3,742·25	2,689·78	....

Table I.—*Production of Gold and Silver from all sources, etc.*—continued.

Mining Centre	Number of Lease	Registered Name of Company or Lease	Total for 1964					Total Production				
			Alluvial	Dollied and Specimens	Ore treated	Gold therefrom	Silver	Alluvial	Dollied and Specimens	Ore treated	Gold therefrom	Silver
			Fine ozs.	Fine ozs.	Tons (2,240 lb.)	Fine ozs.	Fine ozs.	Fine ozs.	Fine ozs.	Tons (2,240 lb.)	Fine ozs.	Fine ozs.
PILBARA GOLDFIELD—continued.												
MARBLE BAR DISTRICT—*continued.*												
Warrawoona	1193	Trump	....	....	61·00	8·34	1·40	....	....	289·50	25·04	2·36
		Voided leases	....	....	....	....	....	....	16·99	17,749·30	19,645·44	23·70
		Sundry claims	....	....	....	....	....	70·98	623·67	6,632·79	4,247·38	·08
Western Shaw	....	Voided leases	....	....	....	....	....	....	....	1,222·50	957·80	....
		Sundry claims	....	....	....	....	....	22·34	67·47	71·50	81·49	....
Wodgina	....	Sundry claims	....	....	....	....	....	....	43·37	·50	....	3·25
Wyman's Well	1084	New Copenhagen	....	....	....	....	....	....	....	770·55	165·52	4·34
		Voided leases	....	....	....	....	....	....	42·86	2,977·29	1,258·44	....
		Sundry claims	....	....	....	....	....	4·47	51·52	2,732·71	1,324·64	1·47
Yandicoogina	....	Voided leases	....	....	....	....	....	....	140·76	3,159·20	6,218·83	....
		Sundry claims	....	....	....	....	....	4·32	239·89	622·25	682·47	45·96
	From District Generally :—											
	Sundry Parcels treated at :											
		State Battery, Bamboo Creek	....	....	....	*6·78	·70	....	....	40·00	*12,156·01	371·34
		State Battery, Marble Bar	....	....	....	*328·88	50·24	....	....	12·00	*12,870·41	145·74
		Various Works	....	....	....	....	....	....	....	380·95	*1,924·48	5·96
		Reported by Banks and Gold Dealers	64·46	....	....	....	·05	14,622·66	457·21	....	15·41	2,224·95
		Total	**190·01**	....	**1,252·00**	**728·14**	**89·98**	**15,504·87**	**4,569·14**	**342,853·72**	**331,273·43**	**32,992·62**
NULLAGINE DISTRICT.												
Eastern Creek	....	Voided leases	....	....	....	....	....	8·96	8·19	5,594·00	9,854·21	14·76
		Sundry claims	....	....	....	....	....	....	12·74	1,481·10	1,627·92	17·02
Elsie	....	Voided leases	....	....	....	....	....	....	....	586·25	1,675·91	....
		Sundry claims	....	....	....	....	....	....	8·28	58·00	188·08	....
McPhee's Creek	....	Voided leases	....	....	....	....	....	....	....	113·00	137·92	....
		Sundry claims	....	....	....	....	....	....	....	134·00	197·09	....
Middle Creek	G.M.L. 229L	Barton	....	....	....	....	....	1·22	....	9,566·75	4,655·81	38·24
	343L	Federation	....	....	105·00	6·52	....	....	....	105·00	6·52	....
	231L, etc.	North-West Mining N.L.	....	....	....	....	....	....	....	9,782·07	6,174·22	....
	231L, etc.	Prior to transfer to present holders	....	....	....	....	....	....	....	53,391·41	32,009·01	10·99
		Voided leases	....	....	....	....	....	....	1·02	18,813·15	11,745·73	8·37
		Sundry claims	....	....	42·00	2·51	....	....	18·69	6,792·60	2,645·65	2·38

Mosquito Creek	331L	Ard Patrick	....	....	....	....	....	10·80	....	78·00	19·75	....
		Voided leases	....	....	....	....	....	1·07	30·12	8,392·30	12,839·13	....
		Sundry claims	....	....	....	....	....	....	181·64	3,707·44	3,789·21	....
Nullagine	292L	Alice	....	2·64	....	....	·16	3·85	1,162·49	138·85	331·29	63·61
		Voided leases	....	....	....	....	....	....	599·59	9,393·75	13,457·00	41·07
		Sundry claims	....	....	23·00	11·43	·17	321·36	689·71	6,663·45	10,575·13	18·62
Spinaway Well	314L	Copper Hills Copper Mine	....	....	....	....	....	....	....	....	‡15·44	‡483·78
		Voided leases	....	....	....	....	....	....	16·97	7,243·70	9,008·65	371·70
		Sundry claims	....	....	....	....	....	33·10	30·50	7,793·85	6,283·29	2·76
	From District Generally :—											
	Sundry Parcels treated at :											
	Barton Battery	....	....	....	....	....	....	....	....	....	*45·19	....
	Various Works	....	....	....	....	....	....	3·89	2·23	145·75	*8,119·30	1·37
	Reported by Banks and Gold Dealers	....	26·43	....	....	....	·17	10,122·70	147·52	....	48·03	6·12
		Total	**26·43**	**2·64**	**170·00**	**20·46**	**·50**	**10,506·95**	**2,909·69**	**149,974·42**	**135,449·48**	**1,080·79**

West Pilbara Goldfield.

Croydon	....	Voided leases	....	....	....	....	....	....	....	8·00	5·44	....
Hong Kong	....	Voided leases	....	....	....	....	....	....	....	331·00	442·45	....
		Sundry claims	....	....	....	....	....	21·40	·02	9·00	3·15	....
Lower Nicol	....	Swelpme	....	....	....	....	....	....	....	119·00	7·02	·60
		Voided leases	....	....	....	....	....	....	1·10	653·20	402·22	....
		Sundry claims	....	....	....	....	....	10·44	2·71	99·00	35·16	·40
Mallina	....	Voided leases	....	....	....	....	....	....	....	141·60	128·44	....
Nicol	....	Voided leases	....	....	....	....	....	....	....	30·00	11·47	....
Pilbara	....	Voided leases	....	....	....	....	....	9·90	48·12	267·00	432·84	....
		Sundry claims	....	....	....	....	....	1·11	86·24	163·00	255·42	....
Roebourne	....	Voided leases	....	....	....	....	....	....	....	2,396·86	1,424·04	385·15
		Sundry claims	....	....	....	....	....	15·47	3·29	1,946·85	817·89	130·21
Station Peak	....	Voided leases	....	....	....	....	....	177·74	41·37	11,016·00	11,388·18	·08
		Sundry claims	....	....	....	....	....	·69	....	86·50	77·23	....
Towranna	....	Voided leases	....	....	....	....	....	....	2·62	3,965·80	5,187·51	....
		Sundry claims	....	....	....	....	....	....	....	22·00	12·35	....
Upper Nicol	....	Sundry claims	....	....	....	....	....	....	....	6·50	2·57	....
Weerianna	....	Voided leases	....	....	....	....	....	....	....	3,200·15	3,214·45	....
		Sundry claims	....	....	....	....	....	....	....	336·00	135·26	1·29
Whim Creek	....	Voided leases	....	....	....	....	....	....	....	....	....	‡883·80

Table I.—*Production of Gold and Silver from all sources, etc.*—continued.

Mining Centre	Number of Lease	Registered Name of Company or Lease	Total for 1964					Total Production				
			Alluvial	Dollied and Specimens	Ore treated	Gold therefrom	Silver	Alluvial	Dollied and Specimens	Ore treated	Gold therefrom	Silver
			Fine ozs.	Fine ozs.	Tons (2,240 lb.)	Fine ozs.	Fine ozs.	Fine ozs.	Fine ozs.	Tons (2,240 lb.)	Fine ozs.	Fine ozs.
		WEST PILBARA GOLDFIELD—continued.										
		From Goldfield Generally :— Sundry Parcels treated at :										
		Various Works	....	....	....	....	....	....	....	....	*102·39	4·90
		Sundry claims	....	....	....	....	....	....	11·77	....	....	†503·36
		Reported by Banks and Gold Dealers	....	....	....	....	....	6,102·62	177·50	103·50	231·54	·87
		Total	....	....	....	....	....	**6,339·37**	**374·74**	**24,900·96**	**24,317·02**	**1,910·66**
		Ashburton Goldfield.										
Belvedere	....	Voided leases	....	....	....	....	....	....	9·88	1,560·00	435·86	176·48
Dead Finish	....	Voided leases	....	....	....	....	....	....	....	1,699·00	874·60	·03
		Sundry claims	....	....	....	....	....	....	11·89	104·25	245·08	....
Linden Station	....	Sundry claims	....	....	....	....	....	....	....	128·35	203·51	....
Melrose	....	Voided leases	....	....	....	....	....	....	....	2,704·00	840·26	213·11
		Sundry claims	....	....	....	....	....	12·41	21·88	562·00	262·78	6·40
Mt. Edith	....	Sundry claims	....	....	....	....	....	....	....	5·00	3·97	....
Mt. Mortimer	....	Sundry claims	....	....	....	....	....	364·63	315·64	44·50	40·25	†74·47
Uaroo	....	Voided leases	....	....	....	....	....	....	....	....	....	†7,713·22
		From Goldfield Generally :—										
		Sundry Claims (Silver-Lead)	....	....	....	....	....	....	....	....	....	†33,787·67
		Reported by Banks and Gold Dealers	1·15	....	....	....	....	8,891·48	123·17	....	7·12	....
		Total	**1·15**	....	....	....	....	**9,268·52**	**482·46**	**6,807·10**	**2,913·43**	**41,971·38**
		Gascoyne Goldfield.										
Bangemall	....	Voided leases	....	....	....	....	....	....	6·22	350·70	313·82	....
		Sundry claims	....	....	....	....	....	88·97	33·55	36·30	203·47	....
Mangaroon Station	G.M.L. 46	Star of Mangaroon	....	·96	155·00	309·67	13·37	....	3·50	460·75	1,027·19	32·67
		Sundry claims	....	....	....	....	....	....	49·09	97·00	376·12	26·92
		From Goldfields generally :—										
		Reported by Banks and Gold Dealers	·36	....	....	....	....	609·52	28·97	....	2·56	....
		Total	**·36**	**·96**	**155·00**	**309·67**	**13·37**	**698·49**	**121·33**	**944·75**	**1,923·16**	**59·59**

Peak Hill Goldfield.

Bulloo Downs	....	Voided leases	....	....	....	....	....	....	....	....	....	50·09
Egerton	....	Voided leases	....	....	....	....	....	62·31	224·68	7,292·25	6,604·91	....
		Sundry claims	....	....	....	....	....	235·35	23·51	1,501·77	791·34	....
Horseshoe	G.M.L. 568P	Horsehoe Lights	....	....	....	....	....	....	....	9,549·00	1,255·34	·34
	568P, etc.	Prior to transfer to present holders	....	....	....	....	....	....	....	139,786·00	23,765·24	1,407·50
		Voided leases	....	....	....	....	....	15·57	1,975·37	5,654·38	2,818·56	2·00
		Sundry claims	....	....	....	....	....	20·12	829·58	2,201·35	809·20	1·14
Jimblebar	....	Voided leases	....	....	....	....	....	....	172·75	7,526·25	2,561·95	·58
		Sundry claims	....	....	....	....	....	13·79	65·95	1,048·05	574·16	....
Mt. Fraser	....	Voided leases	....	....	....	....	....	....	....	399·00	336·28	....
		Sundry claims	....	....	....	....	....	88·28	40·61	480·75	460·12	....
Mt. Seabrook	....	Voided leases	....	....	....	....	....	....	5·05	620·25	428·26	....
		Sundry claims	....	....	....	....	....	....	....	1,089·35	803·12	....
Peak Hill	584P	Dazzle Star	....	....	....	....	....	....	....	329·00	99·97	·50
	567P	Miner Bird	....	....	....	....	....	....	....	2,213·00	967·52	1·68
		Voided leases	....	....	....	....	....	32·28	1,083·61	560,087·28	252,942·37	2,300·43
		Sundry claims	....	18·34	....	....	·67	61·51	324·97	35,365·35	9,030·99	3·43
Ravelstone	....	Voided leases	....	....	....	....	....	....	101·64	4,219·85	3,117·68	....
		Sundry claims	....	....	....	....	....	....	....	553·60	283·17	....
Wilgeena	....	Voided leases	....	....	....	....	....	....	23·54	230·50	156·25	....
Wilthorpe	....	Voided leases	....	....	....	....	....	....	....	47·00	20·93	....
		Sundry claims	....	....	....	....	....	....	....	89·00	25·71	....
Yowereena	....	Voided leases	....	....	....	....	....	....	....	19·50	36·46	....
		Sundry claims	....	....	....	....	....	....	....	117·25	203·16	....
	From Goldfield generally :—											
	Sundry Parcels treated at :											
	State Battery, Peak Hill	....	....	....	....	....	....	....	3·05	15·00	*7,171·41	....
	Various Works	....	....	....	....	....	....	....	....	1,332·00	*7,410·01	23·12
	Reported by Banks and Gold Dealers	....	....	....	....	....	....	2,858·58	444·91	....	15·88	·14
		Total	....	**18·34**	....	....	**·67**	**3,387·79**	**5,319·22**	**781,766·73**	**322,689·99**	**3,790·50**

East Murchison Goldfield.

LAWLERS DISTRICT.

Kathleen Valley	....	Voided leases	....	....	....	....	....	....	144·85	80,963·66	49,054·32	1·57
		Sundry claims	....	....	....	....	....	14·37	526·03	5,836·75	2,662·74	893·45
Lawlers	G.M.L. 1363, etc.	Kim Prospecting and Development Syndicate	....	....	....	....	....	....	....	290·00	25·64	....
	1236	Waroonga	....	....	....	....	....	....	....	....	99·40	·50
		Voided leases	....	....	....	....	....	25·51	692·45	1,622,917·40	575,150·65	14,803·08
		Sundry claims	....	....	....	....	....	401·71	451·61	17,707·48	9,779·27	274·09

Table I.—*Production of Gold and Silver from all sources, etc.*—continued.

Mining Centre	Number of Lease	Registered Name of Company or Lease	Total for 1964: Alluvial	Total for 1964: Dollied and Specimens	Total for 1964: Ore treated	Total for 1964: Gold therefrom	Total for 1964: Silver	Total Production: Alluvial	Total Production: Dollied and Specimens	Total Production: Ore treated	Total Production: Gold therefrom	Total Production: Silver
			Fine ozs.	Fine ozs.	Tons (2,240 lb.)	Fine ozs.	Fine ozs.	Fine ozs.	Fine ozs.	Tons (2,240 lb.)	Fine ozs.	Fine ozs.
EAST MURCHISON GOLDFIELD—continued.												
LAWLERS DISTRICT—continued.												
Sir Samuel	....	Voided leases	....	....	....	....	....	....	359·03	275,417·55	141,829·52	10,234·80
		Sundry claims	....	....	....	....	....	57·64	64·96	7,851·00	4,585·10	·02
Wildara Station	1385	Mangilla	....	....	85·00	146·37	6·25	....	....	85·00	146·37	6·25
	1382, 1383	Rowley's Find Leases	....	....	247·00	118·81	3·94	....	....	247·00	118·81	3·94
	1367	Tahmoo	....	....	341·00	124·72	·22	....	....	1,031·00	399·32	·50
	1372	Vicky Sue	....	....	....	....	....	....	....	63·50	7·67	·50
	1386	Wedge Extended	....	....	36·00	7·99	·43	....	....	36·00	7·99	·43
		Sundry claims	....	....	455·00	300·28	16·78	143·23	....	872·75	532·00	27·31
From District Generally :—												
Sundry Parcels treated at :												
Western Machinery Co. Pty. Ltd.			....	....	....	....	....	....	....	5·00	*4,291·25	29·00
Prior to transfer to present holders			....	....	....	....	....	....	....	....	*1,371·33	15·64
Various Works			....	....	....	....	....	2·12	2·35	1,769·03	*34,159·61	939·39
Reported by Banks and Gold Dealers			....	....	....	....	....	6,458·80	101·91	·05	10·00	....
		Total	....	....	**1,164·00**	**698·17**	**27·62**	**7,103·38**	**2,343·19**	**2,015,093·17**	**824,230·99**	**27,230·47**
WILUNA DISTRICT.												
Coles	....	Voided leases	....	....	....	....	....	....	....	2,765·50	1,240·40	....
		Sundry claims	....	....	10·00	16·49	·85	....	21·03	3,909·50	1,531·71	1·40
Corboy's Find	....	Voided leases	....	....	....	....	....	5·24	1·25	14,946·29	11,036·71	5·00
		Sundry claims	....	....	....	....	....	21·58	....	9,082·35	5,210·79	....
Gum Creek	....	Voided leases	....	....	....	....	....	20·75	....	1,380·00	595·73	....
		Sundry claims	....	....	....	....	....	....	1·36	407·25	131·08	....
Mt. Eureka	....	Voided leases	....	....	....	....	....	....	....	142·25	96·36	....
		Sundry claims	....	....	....	....	....	....	....	783·75	548·56	....
Mt. Keith	....	Voided leases	....	....	....	....	....	....	44·54	20,259·50	13,551·08	....
		Sundry claims	....	....	....	....	....	4·81	227·29	3,868·50	2,485·06	·99
New England	....	Voided leases	....	....	....	....	....	5·74	95·70	5,364·25	3,490·87	....
		Sundry claims	....	....	....	....	....	9·31	5·78	4,534·75	3,111·97	....
Wiluna	....	Voided leases	....	....	....	....	....	....	574·76	8,777,986·65	1,789,127·12	10,049·13
		Sundry claims	....	....	·50	2·00	·73	105·39	225·82	27,443·15	10,899·38	1·06

		From District Generally :—										
		Sundry Parcels treated at :										
		T. J. Jones (L.T.T. 1446H)	....	....	....	*34·08	11·93	....	....	....	*98·71	18·72
		Various Works	....	....	....	....	....	....	....	776·00	*29,001·12	232·42
		Reported by Banks and Gold Dealers	....	....	....	....	....	63·66	56·58	....	158·54	12·02
		Total	....	....	**10·50**	**52·57**	**13·51**	**236·48**	**1,254·11**	**8,873,649·69**	**1,872,315·19**	**10,320·74**

BLACK RANGE DISTRICT.

Barrambie	G.M.L. 1117B	Scheelite Leases	....	....	130·00	82·05	....	....	....	1,031·50	658·95	11·02
		Voided leases	....	....	....	....	....	....	22·49	18,558·42	17,584·28	125·80
		Sundry claims	....	....	14·50	5·80	....	5·07	170·20	993·05	1,068·02	216·73
Bellchambers	....	Voided leases	....	....	....	....	....	....	111·80	4,349·27	3,130·56	....
		Sundry claims	....	....	....	....	....	....	....	1,182·80	557·95	....
Birrigrin	....	Voided leases	....	....	....	....	....	....	820·68	12,042·93	15,086·09	....
		Sundry claims	....	....	....	....	....	....	179·92	2,487·55	1,238·22	....
Curran's Find	....	Voided leases	....	....	....	....	....	18·24	222·89	7,252·25	3,116·68	....
		Sundry claims	....	....	....	....	....	....	29·38	2,158·75	827·18	....
Erroll's	....	Voided leases	....	....	....	....	....	14·17	152·29	14,170·50	9,328·92	....
		Sundry claims	....	....	....	....	....	6·53	399·11	993·75	602·33	·25
Hancocks	....	Voided leases	....	....	....	....	....	....	6,968·16	33,726·00	36,664·76	55·72
		Sundry claims	....	....	....	....	....	4·21	142·89	8,608·10	3,228·18	....
Maninga Marley	....	Voided leases	....	....	....	....	....	....	195·20	60,833·48	48,494·40	22·55
		Sundry claims	....	....	....	....	....	....	158·16	3,079·65	1,768·16	....
Montagu	....	Voided leases	....	....	....	....	....	...	100·17	79,550·60	23,444·82	....
		Sundry claims	....	....	....	....	....	....	71·09	5,041·35	3,171·19	....
Nungarra	....	Voided leases	....	....	....	....	....	25·94	952·34	9,709·00	3,662·96	·25
		Sundry claims	....	....	15·00	6·10	....	50·27	1,458·98	7,697·40	2,966·37	....
Sandstone	958B	Lady Mary	....	....	....	....	....	....	383·35	7,165·75	7,119·35	2·35
		Voided Leases	....	....	....	....	....	4·75	4,449·73	696,625·32	448,299·76	11,754·22
		Sundry claims	....	....	9·00	2·27	....	44·95	1,421·07	16,007·95	6,931·08	....
Youanme	....	Voided leases	....	....	....	....	....	·36	126·92	731,497·55	273,884·97	10,474·10
		Sundry claims	....	....	....	....	....	1·07	18·79	6,258·55	1,814·66	....
		From District Generally :—										
		Sundry Parcels treated at :										
		State Battery, Sandstone	....	....	....	....	....	....	....	290·50	*23,575·34	61·02
		Various Works	....	....	....	....	....	....	....	144·50	*17,000·81	....
		Reported by Banks and Gold Dealers	·42	....	....	....	....	1,495·40	54·36	....	20·38	·15
		Total	**·42**	....	**168·50**	**96·22**	....	**1,670·96**	**18,609·97**	**1,731,456·47**	**955,246·37**	**22,724·16**

Table I.—*Production of Gold and Silver from all sources, etc.*—continued.

Murchison Goldfield.

CUE DISTRICT.

Mining Centre	Number of Lease	Registered Name of Company or Lease	Total for 1964 Alluvial	Total for 1964 Dollied and Specimens	Total for 1964 Ore treated	Total for 1964 Gold therefrom	Total for 1964 Silver	Total Production Alluvial	Total Production Dollied and Specimens	Total Production Ore treated	Total Production Gold therefrom	Total Production Silver
			Fine ozs.	Fine ozs.	Tons (2,240 lb.)	Fine ozs.	Fine ozs.	Fine ozs.	Fine ozs.	Tons (2,240 lb.)	Fine ozs.	Fine ozs.
Big Bell	....	Voided leases	....	....	....	....	....	....	4·49	5,540,872·50	731,131·65	251,816·67
		Sundry claims	....	....	....	....	....	·39	6·32	612·00	490·50	6·71
Cuddingwarra	....	Voided leases	....	....	....	....	....	10·59	132·46	102,115·91	56,152·11	100·71
		Sundry claims	....	....	....	....	....	18·46	384·38	10,520·39	5,761·20	18·42
Cue	....	Voided leases	....	....	....	....	....	202·71	911·60	292,424·49	222,335·12	73·03
		Sundry claims	....	....	43·25	14·40	·40	252·92	894·70	47,462·99	20,562·99	5·13
Eelya	....	Eagle Hawk	....	....	....	....	....	....	....	150·25	25·44	·73
		Voided leases	....	....	....	....	....	....	8·78	2,477·75	2,228·56	....
		Sundry claims	....	....	....	....	....	6·20	143·81	2,309·90	1,099·24	1·31
Mindoolah	....	Voided leases	....	....	....	....	....	3·07	2·54	9,380·28	5,672·31	42·97
		Sundry claims	....	....	....	....	....	....	29·30	3,309·85	2,347·36	....
Reedy's	G.M.L. 2289	New Rand	....	....	818·25	181·50	8·99	....	....	818·25	181·50	8·99
	2287	Rand No. 3	....	....	311·25	89·52	2·90	....	....	567·25	138·52	5·51
		Voided leases	....	....	....	....	....	2·82	219·70	729,693·43	240,349·10	20,467·28
		Sundry claims	....	....	....	....	....	170·71	137·16	7,295·00	2,690·88	1·24
Tuckabianna	2237	Gidgie	....	....	17·50	2·77	·12	....	297·73	3,120·15	2,186·15	36·35
		Voided leases	....	....	....	....	....	649·70	996·22	13,968·23	7,833·32	4·05
		Sundry Claims	....	....	....	....	....	162·21	489·40	5,777·35	2,810·85	1·32
Tuckanarra	....	Voided leases	....	....	....	....	....	85·37	3,511·10	19,490·00	22,828·99	172·77
		Sundry claims	....	....	....	....	....	115·23	797·89	10,196·82	10,313·22	6·13
Weld Range	....	Voided leases	....	....	....	....	....	....	23·64	2,169·75	1,137·11	....
		Sundry claims	....	....	....	....	....	....	3·90	1,438·50	1,136·41	....
		From District generally :—										
		Sundry Parcels treated at :										
		M. Hronsky (L.T.T. 1467H)	....	....	....	*119·83	286·27	....	....	....	228·11*	561·14
		State Battery, Cue	....	....	....	....	....	....	....	76·25	*26,818·66	127·53
		Various Works	....	....	....	....	....	....	....	8,615·52	*36,008·51	1,232·12
		Reported by Banks and Gold Dealers	2·58	....	....	....	....	3,443·93	109·87	....	22·62	·65
		Total	**2·58**	....	**1,190·25**	**408·02**	**298·68**	**5,124·31**	**9,104·99**	**6,814,862·81**	**1,402,490·43**	**274,684·76**

MEEKATHARRA DISTRICT.

Abbotts	....	Voided leases	....	....	....	....	....	....	26·45	36,841·35	38,775·28	....
		Sundry claims	....	....	....	....	....	....	5·29	3,951·57	2,357·54	....
Burnakurra	....	Voided leases	....	....	....	....	....	....	3,247·59	39,387·45	30,920·76	26·90
		Sundry claims	....	....	....	....	....	17·03	129·24	2,486·55	1,310·84	1·54
Chesterfield	....	Voided leases	....	....	....	....	....	29·02	420·32	11,987·26	8,656·61	25·84
		Sundry claims	....	....	....	....	....	....	42·19	1,069·05	776·69	....
Gabanintha	....	Voided leases	....	....	....	....	....	11·79	38·14	33,344·60	22,346·06	830·21
		Sundry claims	....	....	....	....	....	16·78	159·05	5,391·50	3,020·00	3·67
Garden Gully	....	Voided leases	....	....	....	....	....	26·36	74·91	30,272·07	21,864·74	1,102·59
		Sundry claims	....	....	....	....	....	....	18·74	3,023·69	1,725·84	·38
Gum Creek	....	Voided leases	....	....	....	....	....	25·27	91·96	3,893·08	3,819·91	....
		Sundry claims	....	....	....	....	....	4·37	84·86	735·05	656·05	....
Holden's Find	....	Voided leases	....	....	....	....	....	....	18·99	18,061·00	7,320·42	....
		Sundry claims	....	....	....	....	....	164·95	49·07	425·15	279·25	....
Jillawarra	....	Voided leases	....	....	....	....	....	....	1,263·53	1,999·80	3,565·40	....
		Sundry claims	....	....	....	....	....	173·02	150·04	443·75	404·77	....
Meeka Pools	....	Voided leases	....	....	....	....	....	....	....	111·58	82·27	....
		Sundry claims	....	....	....	....	....	....	2·84	233·57	205·38	....
Meekatharra	G.M.L. 1991N	Commodore	....	....	....	....	....	....	....	37·00	45·79	·23
	2000N	Halcyon	....	....	1,090·00	60·37	2·31	....	....	1,853·00	100·97	3·82
	2004N	Hawk Hill	....	....	10·75	39·80	1·97	....	....	10·75	39·80	1·97
	1559N	Ingliston	....	....	....	....	....	....	498·32	3,223·85	1,895·45	·32
	1999N	Ingliston, South	....	....	....	....	....	....	....	82·50	11·88	·58
	1529N	Prohibition	....	....	1,635·75	96·35	1·46	....	....	10,087·75	2,471·31	11·39
	1529N, etc.	Prior to transfer to present holders	....	....	....	....	....	....	....	54,266·25	9,949·61	11·83
		Voided leases	....	....	....	....	....	181·39	1,708·02	1,717,771·57	929,313·04	2,472·84
		Sundry claims	....	....	277·00	17·12	·33	279·84	1,009·74	32,074·45	11,660·80	4·74
Mistletoe	....	Voided leases	....	....	....	....	....	4·15	1,000·24	417·00	486·21	....
		Sundry claims	....	....	....	....	....	119·14	71·85	19·75	2·03	....
Mt. Maitland	....	Voided leases	....	....	....	....	....	....	....	88·00	80·11	....
		Sundry claims	....	....	....	....	....	....	....	420·75	240·86	....
Munara Gully	....	Voided leases	....	....	....	....	....	....	....	13,283·50	6,559·93	....
		Sundry claims	....	....	....	....	....	....	34·23	1,009·75	373·74	....
Nanardie Well	2003N	Poplar	....	....	31·25	96·93	5·30	....	....	48·25	128·98	7·40
Nannine	....	Voided leases	....	....	....	....	....	47·31	844·02	129,492·88	76,482·78	167·45
		Sundry claims	....	....	....	....	....	138·95	1,301·28	6,775·18	4,787·62	4·55
Quinns	....	Voided leases	....	....	....	....	....	7·30	1,186·50	33,356·91	13,464·37	90·70
		Sundry claims	....	....	....	....	....	15·07	1,289·65	3,841·67	2,718·33	....

Table I.—*Production of Gold and Silver from all sources, etc.*—continued.

Mining Centre	Number of Lease	Registered Name of Company or Lease	Total for 1964: Alluvial	Total for 1964: Dollied and Specimens	Total for 1964: Ore treated	Total for 1964: Gold therefrom	Total for 1964: Silver	Total Production: Alluvial	Total Production: Dollied and Specimens	Total Production: Ore treated	Total Production: Gold therefrom	Total Production: Silver
			Fine ozs.	Fine ozs.	Tons (2,240 lb.)	Fine ozs.	Fine ozs.	Fine ozs.	Fine ozs.	Tons (2,240 lb.)	Fine ozs.	Fine ozs.
		MURCHISON GOLDFIELD—continued.										
		MEEKATHARRA DISTRICT—*continued.*										
Ruby Well	....	Voided leases	....	....	....	....	....	....	43·46	7,461·00	4,046·70	....
		Sundry claims	....	....	....	....	....	1,015·87	409·39	520·25	629·60	....
Stake Well	....	Voided leases	....	....	....	....	....	....	200·12	21,362·00	9,566·18	....
		Sundry claims	....	....	....	....	....	31·91	34·73	1,003·60	584·54	....
Star of the East	....	Voided leases	....	....	....	....	....	....	....	27,244·00	20,305·40	....
		Sundry claims	....	....	....	....	....	....	....	127·62	94·97	....
Yaloginda	1853N	Bluebird	....	....	....	....	....	....	....	10,519·50	3,041·77	2·57
		Voided leases	....	....	....	....	....	19·03	1,972·23	28,175·54	14,609·36	8·68
		Sundry claims	....	....	....	....	....	61·89	647·51	11,688·67	5,117·67	·93
		From District generally :—										
		Sundry Parcels treated at :										
		F. M. Scott (L.T.T. 1506H)	....	....	36·50	*196·95	25·24	....	....	49·00	*257·20	34·59
		State Battery, Meekatharra	....	....	....	*552·56	....	....	....	193·00	*28,574·29	25·13
		Various Works	....	....	....	....	....	....	....	3,947·30	*13,962·97	391·20
		Reported by Banks and Gold Dealers	6·44	....	....	....	·47	12,259·79	185·53	451·50	97·71	2·23
		Total	**6·44**	....	**3,081·25**	**1,060·08**	**37·08**	**14,650·23**	**18,260·03**	**2,314,561·81**	**1,309,789·78**	**5,234·28**
		DAY DAWN DISTRICT.										
Day Dawn	G.M.L. 573D, etc.	Mountain View Gold N.L.	....	....	180·25	59·13	5·02	....	....	13,792·35	17,435·98	222·62
		Prior to transfer to present holders	....	....	....	....	....	6·12	100·89	13,290·78	33,849·98	....
		Voided leases	....	....	....	....	....	160·64	826·65	1,922,088·36	1,225,599·75	169,210·44
		Sundry claims	....	....	....	....	....	96·42	523·56	13,660·51	6,773·85	2·89
Lake Austin	....	Voided leases	....	....	....	....	....	613·00	3,079·62	36,872·20	51,050·49	....
		Sundry claims	9·80	....	....	....	·69	69·87	965·49	3,663·19	1,360·99	5·67
Mainland	....	Voided leases	....	....	....	....	....	·41	3,296·77	7,575·62	25,026·07	....
		Sundry claims	....	....	....	....	....	17·85	771·56	1,337·95	701·31	....
Pinnacles	G.M.L. 664D	Eclipse	....	....	....	....	....	....	....	282·75	29·73	....
	676D	Eclipse Amalgamated North	....	....	....	....	....	....	....	187·50	17·68	....
	670D	Eclipse North	....	....	....	....	....	....	....	840·00	47·62	....
		Voided leases	....	....	....	....	....	4·90	1,213·68	18,280·00	9,915·71	....
		Sundry claims	....	....	....	....	....	62·93	509·50	4,678·17	1,801·29	....

From District generally :—												
Sundry Parcels treated at :												
Various Works			....	....	....	....	....	....	16·61	988·00	*1,996·97	·59
Reported by Banks and Gold Dealers			·09	....	....	....	....	2,223·92	37·47	....	12·57	·01
		Total	**9·89**	....	**180·25**	**59·13**	**5·71**	**3,255·06**	**11,341·80**	**2,037,537·38**	**1,375,619·99**	**169,442·22**

MOUNT MAGNET DISTRICT.

Jumbulyer	G.M.L. 1410M	Gold Bug	....	....	....	....	....	....	2·20	927·35	277·15	....
	1657M	Olden	....	....	44·00	16·50	1·17	....	....	44·00	16·50	1·17
		Voided leases	....	....	....	....	....	....	13·37	680·10	361·74	....
		Sundry claims	....	....	....	....	....	20·32	116·27	1,216·70	886·47	....
Lennonville	1566M	Empress	....	....	....	....	....	....	....	....	9·51	....
	1637M	Long Reef South	....	....	....	....	....	....	....	224·75	230·27	9·69
	1651M	Nodoe	....	....	139·00	108·49	3·42	....	....	223·50	205·45	6·05
	1596M	Wheel of Fortune South	....	....	8·50	26·28	2·25	....	....	26·50	77·65	2·25
		Voided leases	....	....	....	....	....	....	3,226·91	151,502·55	128,568·28	459·62
		Sundry claims	....	....	65·00	14·05	·40	26·00	108·82	15,435·52	6,003·48	9·23
Mt. Magnet	1527M, etc.	Eclipse Gold Mine N.L.	....	....	....	....	....	....	12·20	36,408·00	41,852·01	4,618·48
		Prior to transfer to present holders	....	....	....	....	....	....	....	294·10	170·77	1·34
	1255M, (1415M)	Edward Carson Leases	....	....	....	2·38	·26	1·82	....	18,042·75	12,910·93	8·02
	1455M	Evening Star	....	....	....	....	....	....	....	1,083·25	124·35	....
	1287M	Havelock	....	....	....	....	....	....	11·05	4,332·50	840·14	....
	1282M, etc.	Hill 50 Gold Mine N.L.	....	....	185,232·00	69,553·48	5,370·56	....	....	2,205,313·40	1,091,797·27	48,702·61
		Prior to transfer to present holders	....	....	....	....	....	....	829·41	8,787·65	4,122·61	·21
	1361M	Jupiter	....	....	....	....	....	....	·83	658·05	261·71	....
	1444M	Late Comer	....	....	....	....	....	....	2·53	511·00	391·31	....
	1447M	Morning Star	....	....	....	....	....	....	....	2,135·40	483·54	1·53
	1475M	Morning Star North	....	....	....	....	....	....	....	11·75	8·13	....
	1536M	Pat O'Meara	....	....	....	....	....	....	....	34·00	·68	....
	1505M	Perseverance	....	....	....	....	....	....	....	107·25	11·40	....
	1654M	Susan Jane	....	....	....	....	....	....	....	8·00	13·71	·45
	1588M	Three Boys	....	....	....	....	....	....	11·11	48·00	2·47	1·11
		Voided leases	....	....	....	....	....	29·26	9,811·54	834,437·81	312,786·26	851·39
		Sundry claims	....	....	136·25	85·06	5·62	157·95	2,626·24	61,390·17	30,094·10	20·35
Mt. Magnet, East	....	Voided leases	....	....	....	....	....	63·29	764·53	5,522·28	2,811·75	....
		Sundry claims	....	....	....	....	....	....	37·22	418·25	428·29	....
Moyagee	1538M	Moyagee	....	....	....	....	....	....	....	33·75	34·88	....
		Voided leases	....	....	....	....	....	....	23·59	12,439·10	18,299·16	757·77
		Sundry claims	....	....	....	....	....	14·44	176·21	1,550·75	1,752·39	....
Paynesville	....	Voided leases	....	....	....	....	....	....	1,613·34	449·77	1,116·15	....
		Sundry claims	....	....	....	....	....	3·36	540·21	882·57	1,372·00	....
Winjangoo	....	Voided leases	....	....	....	....	....	·99	202·16	366·25	99·08	1·51
		Sundry claims	....	....	....	....	....	....	223·32	237·53	71·58	....

Table I.—*Production of Gold and Silver from all sources, etc.*—continued.

Mining Centre	Number of Lease	Registered Name of Company or Lease	Total for 1964					Total Production				
			Alluvial	Dollied and Specimens	Ore treated	Gold therefrom	Silver	Alluvial	Dollied and Specimens	Ore treated	Gold therefrom	Silver
			Fine ozs.	Fine ozs.	Tons (2,240 lb.)	Fine ozs.	Fine ozs.	Fine ozs.	Fine ozs.	Tons (2,240 lb.)	Fine ozs.	Fine ozs.
MURCHISON GOLDFIELD—continued.												
MOUNT MAGNET DISTRICT—*continued.*												
		From District generally :										
		Sundry Parcels treated at :										
		P. Sciarisa (L.T.T. 1477H)	....	....	....	*61·58	4·55	....	....	·25	*330·72	24·27
		State Battery, Boogardie	....	....	....	....	....	....	....	348·26	*35,102·45	15·62
		Various Works	....	....	....	....	....	....	....	100·31	*18,978·47	12·48
		Reported by Banks and Gold Dealers	·07	....	....	....	....	2,317·87	114·69	8·00	113·15	·26
		Total	**·07**	....	**185,624·75**	**69,867·82**	**5,388·23**	**2,635·30**	**20,467·75**	**3,366,241·12**	**1,713,008·96**	**55,505·41**

Yalgoo Goldfield.

Mining Centre	Number of Lease	Registered Name of Company or Lease	Alluvial (1964)	Dollied and Specimens (1964)	Ore treated (1964)	Gold therefrom (1964)	Silver (1964)	Alluvial (Total)	Dollied and Specimens (Total)	Ore treated (Total)	Gold therefrom (Total)	Silver (Total)
Bilberatha	....	Voided leases	....	....	....	....	....	1·27	90·94	3,384·50	1,845·05	....
		Sundry claims	....	....	....	....	....	....	6·64	3,075·05	1,401·56	....
Carlaminda	....	Voided leases	....	....	....	....	....	1·28	3·39	2,056·57	862·42	3·30
		Sundry claims	....	....	....	....	....	....	....	1,368·50	600·68	....
Fields Find	G.M.L. 1207	Rose Marie	....	....	....	....	....	....	....	418·67	254·46	1·59
		Voided leases	....	....	....	....	....	....	226·72	50,316·71	33,692·51	58·08
		Sundry claims	....	....	....	....	....	5·77	188·67	5,558·85	1,783·13	·15
Goodingnow	1063	Ark	....	....	....	....	....	....	12·49	2,270·50	1,927·29	....
		Voided leases	....	....	....	....	....	146·70	299·28	81,813·71	66,366·75	·68
		Sundry claims	....	....	....	....	....	152·96	169·70	10,433·05	5,136·08	·14
Gullewa	....	Voided leases	....	....	....	....	....	....	19·05	39,913·60	20,966·51	113·70
		Sundry claims	....	....	....	....	....	....	170·45	4,391·25	1,918·24	....
Kirkalucka	....	Voided leases	....	....	....	....	....	....	....	61·25	45·10	....
		Sundry claims	....	....	....	....	....	....	17·79	257·30	126·29	....
Messenger's Patch	....	Voided leases	....	....	....	....	....	8·64	349·71	39,836·51	28,585·68	1,083·01
		Sundry claims	....	....	....	....	....	463·12	333·98	1,595·10	588·36	·07
Mt. Farmer	....	Voided leases	....	....	....	....	....	....	....	64·00	40·19	....
		Sundry claims	....	....	....	....	....	....	....	462·90	145·06	....
Mt. Gibson	....	Voided leases	....	....	....	....	....	....	6·44	526·50	888·70	....
		Sundry claims	....	....	....	....	....	3·95	44·72	11,52·60	502·15	1·00
Ninghan	....	Voided leases	....	....	....	....	....	....	....	10·00	1·41	....
		Sundry claims	....	....	....	....	....	....	....	324·75	123·28	....

Noongal	....	Voided leases	....	....	....	....	....	7·88	31·96	11,263·75	5,771·66	4·04
		Sundry claims	....	....	....	....	....	39·32	310·31	8,506·55	3,590·35	1·16
Nyounda	....	Voided leases	....	....	....	....	....	....	217·63	416·00	183·91	....
		Sundry claims	....	....	....	....	....	....	30·88	1,229·00	240·38	·54
Pinyalling	....	Voided leases	....	....	....	....	....	....	313·79	2,318·90	1,146·19	....
		Sundry clains	....	....	....	....	....	3·27	134·09	1,500·00	959·31	....
Retaliation	....	Voided leases	....	....	....	....	....	....	....	5,089·25	1,872·98	....
		Sundry claims	....	....	....	....	....	....	....	913·25	321·52	....
Rothsay	....	Voided leases	....	....	....	....	....	....	24·06	40,680·75	10,777·98	....
		Sundry claims	....	....	....	....	....	....	·73	6,469·50	2,562·03	....
Wadgingarra	....	Voided leases	....	....	....	....	....	....	....	691·11	650·63	....
		Sundry claims	....	....	....	....	....	....	....	2,147·30	596·20	2·65
Warda Warra	....	Voided leases	....	....	....	....	....	....	....	10,760·50	5,862·04	....
		Sundry claims	....	....	....	....	....	....	....	1,108·75	508·63	8·53
Warriedar	....	Voided leases	....	....	....	....	....	....	....	13,661·50	4,607·88	7·30
		Sundry claims	....	....	....	....	....	....	2·84	8,867·85	1,950·54	4·54
Yalgoo	....	Voided leases	....	....	....	....	....	....	3·23	6,314·50	9,965·18	....
		Sundry claims	....	....	....	....	....	....	23·56	2,622·75	1,010·02	....
Yuin	....	Voided leases	....	....	....	....	....	....	127·12	68,139·50	27,908·57	130·13
		Sundry claims	....	....	....	....	....	....	4·70	335·50	67·53	....
	From Goldfield generally :— Sundry Parcels treated at :											
		State Battery, Payne's Find	....	....	....	....	....	....	....	156·50	*4,548·42	....
		Various Works	....	....	....	....	....	9·42	....	865·00	*11,084·64	100·91
		Reported by Banks and Gold Dealers	·39	....	....	....	....	965·19	58·32	....	48·90	·89
		Total	·39	....	....	....	....	1,808·77	3,223·19	443,349·58	264,036·39	1,522·41

Mt. Margaret Goldfield.

MOUNT MORGANS DISTRICT.

Australia United....	....	Voided leases	....	....	....	....	....	....	1,911·63	15,913·69	23,305·76	1·76
		Sundry claims	....	....	....	....	....	....	580·98	1,307·50	2,227·65	....
Eucalyptus	....	Voided leases	....	....	....	....	....	....	2,878·56	1,603·85	3,251·01	....
		Sundry claims	....	....	....	....	....	....	591·62	2,160·30	2,011·78	....
Jasper Hill (Irwin Hills)	....	Sundry claims	....	....	75·00	8·89	·53	....	....	75·00	8·89	·53
Linden	....	Voided leases	....	....	....	....	....	7·53	566·97	72,919·81	66,208·35	·68
		Sundry claims	....	....	60·00	27·16	1·29	132·11	244·96	19,667·35	13,866·26	1·69

Table I.—*Production of Gold and Silver from all sources, etc.*—continued.

Mining Centre	Number of Lease	Registered Name of Company or Lease	Total for 1964					Total Production				
			Alluvial	Dollied and Specimens	Ore treated	Gold therefrom	Silver	Alluvial	Dollied and Specimens	Ore treated	Gold therefrom	Silver
			Fine ozs.	Fine ozs.	Tons (2,240 lb.)	Fine ozs.	Fine ozs.	Fine ozs.	Fine ozs.	Tons (2,240 lb.)	Fine ozs.	Fine ozs.
		MOUNT MARGARET GOLDFIELD—continued. **MOUNT MORGANS DISTRICT.**										
Mt. Margaret	....	Voided Leases	....	....	....	....	....	12·13	1·89	8,900·39	5,291·51	12·55
		Sundry claims	....	....	....	....	....	25·22	111·18	1,790·10	661·42	....
Mt. Morgans	G.M.L.'s 399F, etc.	Morgans Gold Mines Ltd.	....	....	....	....	....	....	....	5,070·05	13,981·69	....
		Prior to transfer to present holders	....	....	....	....	....	....	16·66	779,578·43	354,225·86	5,552·63
		Voided leases	....	....	....	....	....	17·95	148·79	61,354·50	34,786·53	77·86
		Sundry claims	....	....	....	....	....	36·41	398·78	5,104·07	3,396·77	....
Murrin Murrin	....	Voided leases	....	....	....	....	....	10·43	231·35	136,940·22	104,029·97	29·60
		Sundry claims	....	3·47	89·00	6·50	·59	51·15	560·71	6,887·68	4,785·37	16·19
Redcastle	....	Voided leases	....	....	....	....	....	4·49	491·33	4,284·95	4,111·85	....
		Sundry claims	....	....	....	....	....	....	113·84	1,183·57	642·45	....
Yundamindera	....	Voided leases	....	....	....	....	....	....	110·93	84,523·85	52,042·94	36·50
		Sundry claims	....	....	....	....	....	3·01	271·93	6,674·35	4,789·46	....
	From District generally :— Sundry Parcels treated at :											
	Various Works	....	....	....	....	....	....	113·08	28·03	1,970·35	*24,226·82	100·06
	Reported by Banks and Gold Dealers	....	....	....	....	....	....	3,157·72	141·84	10·30	95·75	·68
		Total	....	**3·47**	**224·00**	**42·55**	**2·41**	**3,571·23**	**9,361·98**	**1,217,920·31**	**717,948·09**	**5,830·73**
		MOUNT MALCOLM DISTRICT.										
Cardinia	....	Voided leases	....	....	....	....	....	13·87	1,598·15	5,531·74	4,238·57	....
		Sundry claims	....	....	40·00	26·78	2·73	4·25	121·91	1,988·25	670·64	5·60
Diorite King	....	Voided leases	....	....	....	....	....	....	945·65	38,879·03	35,144·28	33·18
		Sundry claims	....	....	....	....	....	11·21	332·13	4,655·85	4,514·02	....
Dodger's Well	....	Voided leases	....	....	....	....	....	....	57·90	1,373·30	1,936·52	....
		Sundry claims	....	....	....	....	....	·95	28·32	1,440·25	904·23	....
Lake Darlot	G.M.L. 1845C....	Monte Christo	....	....	1,372·50	100·01	2·09	....	....	8,310·25	637·19	8·62
		Voided leases	....	....	....	....	....	....	4,482·18	74,717·46	52,293·77	7·56
		Sundry claims	....	....	276·00	154·54	11·00	129·92	906·52	12,168·62	6,713·96	40·87
Leonora	1829C	Jessie Alma	....	....	144·00	10·35	·79	....	582·87	871·25	1,930·88	·79
	1849C	Puzzle	....	....	31·00	32·83	1·76	....	....	95·00	130·29	4·87
	1579C	Sons of Gwalia Ltd.	....	....	....	440·46	65·97	....	....	7,030,740·53	2,580,851·91	188,804·14
		Prior to transfer to present holders	....	....	....	....	....	....	....	109,081·00	55,989·21	8·66

	1848C	Tower Hill	....	....	65·00	4·91	·23	....	....	1,499·75	196·54	9·06
	1847C	Victor	....	....	15·00	7·21	·29	....	2·34	43·50	49·46	·73
		Voided leases	....	....	....	....	....	....	1,866·86	176,575·00	91,197·84	94·57
		Sundry claims	....	....	297·50	75·39	5·22	37·73	377·26	22,159·45	12,716·84	25·37
Malcolm	....	Voided leases	....	....	....	....	....	11·65	47·07	62,656·53	47,563·43	....
		Sundry claims	....	....	21·00	2·04	·26	5·75	35·60	4,969·47	2,731·02	1·85
Mertondale	....	Voided leases	....	....	....	....	....	....	....	89,024·75	60,935·32	1,497·58
		Sundry claims	....	....	50·00	3·26	·32	5·42	85·74	3,266·41	2,298·78	·32
Mt. Clifford	....	Voided leases	....	....	....	....	....	....	1,786·51	9,588·96	16,640·81	....
		Sundry claims	....	....	....	....	....	53·98	1,860·00	5,602·70	3,494·04	·24
Pig Well	....	Voided leases	....	....	....	....	....	....	....	13,587·32	14,676·58	63·68
		Sundry claims	....	....	....	....	....	....	34·61	2,896·65	1,225·46	....
Randwick	....	Voided leases	....	....	....	....	....	....	246·76	10,912·65	9,736·57	....
		Sundry claims	....	....	....	....	....	66·57	164·02	2,551·64	1,320·66	....
Webster's Find	....	Voided leases	....	....	....	....	....	30·30	....	22,167·50	14,377·65	....
		Sundry claims	....	....	....	....	....	36·84	695·68	2,356·15	1,530·56	....
Wilson's Creek	....	Voided leases	....	....	....	....	....	....	....	333·50	168·27	....
		Sundry claims	....	....	....	....	....	·70	4·24	316·00	261·12	....
Wilson's Patch	....	Voided leases	....	....	....	....	....	....	99·38	28,863·35	13,050·19	1·05
		Sundry claims	....	....	....	....	....	4·68	54·46	1,700·16	1,433·20	·96
		From District generally :—										
		Sundry Parcels treated at :										
		State Battery, Lake Darlot	....	....	....	....	....	....	....	18·00	*2,514·77	4·98
		Various Works	....	....	....	....	....	....	....	809·50	*25,301·30	158·35
		Reported by Banks and Gold Dealers	5·11	....	....	....	·67	3,653·16	252·83	46·50	57·80	·67
		Total	**5·11**	....	**2,312·00**	**857·78**	**91·33**	**4,066·98**	**16,668·99**	**7,751,797·97**	**3,069,433·68**	**190,773·70**

MOUNT MARGARET DISTRICT.

Burtville	G.M.L. 2567T....	Boomerang	....	....	....	....	....	....	....	578·00	34·08	3·67
		Voided leases	....	....	....	....	....	4·89	419·10	74,268·45	122,454·22	948·27
		Sundry Claims	....	....	....	....	....	2·65	208·27	8,677·66	5,673·60	....
Duketon	....	Voided leases	....	....	....	....	....	5·35	3,216·10	31,889·42	22,542·63	....
		Sundry claims	....	....	....	....	....	85·07	528·26	2,442·65	2,196·49	29·76
Eagle's Nest	....	Voided leases	....	....	....	....	....	....	145·34	534·50	1,238·22	....
		Sundry claims	....	....	....	....	....	24·07	487·05	1,046·35	360·11	....
Erlistoun	....	Voided leases	....	....	....	....	....	10·07	393·41	156,731·00	101,641·56	4,327·81
		Sundry claims	....	....	....	....	....	1,181·65	165·05	5,716·59	3,888·89	....
Euro	....	Voided leases	....	....	....	....	....	....	65·14	91,821·50	37,678·25	....
		Sundry claims	....	....	....	....	....	4·87	73·04	1,507·00	835·30	....

Table I.—*Production of Gold and Silver from all sources, etc.*—continued.

MOUNT MARGARET GOLDFIELD—continued.

MOUNT MARGARET DISTRICT—continued.

Mining Centre	Number of Lease	Registered Name of Company or Lease	Total for 1964: Alluvial	Total for 1964: Dollied and Specimens	Total for 1964: Ore Treated	Total for 1964: Gold Therefrom	Total for 1964: Silver	Total Production: Alluvial	Total Production: Dollied and Specimens	Total Production: Ore Treated	Total Production: Gold Therefrom	Total Production: Silver
			Fine ozs.	Fine ozs.	Tons (2,240 lb.)	Fine ozs.	Fine ozs.	Fine ozs.	Fine ozs.	Tons (2,240 lb.)	Fine ozs.	Fine ozs.
Laverton	....	Voided leases	....	....	....	....	....	28·59	2,028·85	2,131,121·12	820,120·06	56,945·78
		Sundry claims	....	....	....	....	....	215·58	1,492·90	17,552·50	9,256·80	....
Mt. Barnicoat	....	Voided leases	....	....	....	....	....	....	23·08	2,370·00	2,251·99	....
		Sundry claims	....	....	....	....	....	....	·68	1,309·75	1,087·77	....
Mt. Shenton	....	Voided leases	....	....	....	....	....	....	....	15·00	26·65	....
		Sundry claims	....	....	....	....	....	....	....	279·25	209·67	....
	From District Generally :—											
	Sundry Parcels treated at :											
		State Battery, Laverton	....	....	....	....	....	....	....	97·50	*19,327·97	561·11
		Various Works	....	....	....	....	....	....	....	215·00	*23,190·12	3,374·30
		Reported by Banks and Gold Dealers	....	....	....	....	....	2,580·75	108·08	....	29·18	....
		Total	....	....	....	....	....	**4,143·54**	**9,354·35**	**2,528,173·24**	**1,174,043·56**	**66,190·70**

North Coolgardie Goldfield.

MENZIES DISTRICT.

Mining Centre	Number of Lease	Registered Name of Company or Lease	Total for 1964: Alluvial	Total for 1964: Dollied and Specimens	Total for 1964: Ore Treated	Total for 1964: Gold Therefrom	Total for 1964: Silver	Total Production: Alluvial	Total Production: Dollied and Specimens	Total Production: Ore Treated	Total Production: Gold Therefrom	Total Production: Silver
Comet Vale	G.M.L. 5766Z	Coonega Extended	....	....	....	....	....	....	....	100·25	35·55	....
		Voided leases	....	....	....	....	....	....	419·74	267,668·97	193,272·82	5,355·33
		Sundry claims	....	....	....	....	....	....	40·19	2,236·96	1,176·14	....
Goongarrie	5740Z	Gulls Blow	....	....	....	....	....	....	164·75	374·75	265·78	....
		Voided leases	....	....	....	....	....	·94	1,385·26	29,897·79	18,124·83	....
		Sundry claims	....	....	64·50	15·24	....	46·46	2,144·42	2,952·60	3,398·61	....
Menzies	5793Z	Black Swan	....	....	322·75	25·70	....	....	....	796·50	59·20	....
	5794Z	Callie	....	....	219·00	60·55	....	....	....	219·00	60·55	....
	5511Z	First Hit	....	....	282·75	41·47	1·63	....	....	7,193·75	7,785·27	24·00
	5511Z	(First Hit Gold Mines (1934) Ltd.)	....	....	....	....	....	....	....	68,473·70	49,060·96	6,676·23
	5788Z	Flying Fish	....	11·06	152·25	11·88	·85	....	11·06	443·50	55·26	·85
	5542Z	Good Block	....	....	326·00	13·32	....	....	7·32	3,876·05	3,096·41	....
	5780Z	Good Enough	....	....	124·00	11·07	....	....	....	3,864·70	1,041·58	1·54
	5795Z	Little Wonder	....	....	111·00	8·01	....	....	....	186·00	18·99	....
	5520Z	Mignonette	....	....	....	....	....	....	....	808·50	404·43	....
		Voided leases	....	....	....	....	....	45·42	1,260·24	939,406·13	729,011·90	13,595·47
		Sundry claims	....	....	1,005·00	76·54	·24	56·87	624·33	40,640·59	26,361·62	813·10

Mt. Ida	5701Z, etc.	Moonlight Wiluna Gold Mines Ltd.	....	....	29,353·00	14,386·42	2,355·23	....	40·77	398,824·86	206,714·29	3,612·39
		Prior to transfer to present holders	....	....	....	....	....	....	....	31,833·25	16,021·98	891·37
		Voided leases	....	....	....	....	....	....	92·21	68,748·92	72,681·44	106·63
		Sundry claims	....	....	....	....	....	48·14	436·08	16,117·41	8,280·58	·12
Twin Hills	....	Voided leases	....	....	....	....	....	....	....	582·30	574·93	....
		Sundry claims	....	....	....	....	....	....	....	97·80	86·69	....
		From District generally :—										
		Sundry Parcels treated at :										
		State Battery, Mt. Ida	....	....	....	....	....	....	....	1,866·25	*7,556·16	2·04
		State Battery, Menzies	....	....	20·00	*109·57	75·23	....	....	20·00	*3,803·24	1,032·66
		Various Works	....	....	....	....	....	....	....	3,216·05	*58,804·12	3,062·11
		Reported by Banks and Gold Dealers	·50	....	....	....	....	1,495·99	403·22	100·00	48·49	....
		Total	**·50**	**11·06**	**31,980·25**	**14,759·77**	**2,433·18**	**1,693·82**	**7,029·59**	**1,890,546·58**	**1,407,801·82**	**35,173·84**

ULARRING DISTRICT.

Davyhurst	....	Voided leases	....	....	....	....	....	2·93	152·64	304,354·62	195,751·92	21,336·15
		Sundry claims	....	....	....	....	....	....	208·48	14,160·19	5,787·29	....
Morleys	G.M.L. 1094U	First Hit	....	82·48	129·75	104·55	....	....	82·48	5,349·00	7,258·82	11·40
	1168U	Hazel Dawn	....	....	....	....	....	....	....	51·25	104·97	....
	1081U	Mabel Gertrude	....	....	90·75	96·74	....	....	17·19	1,811·25	2,114·08	....
	1089U	Paramount	....	....	....	....	....	....	1·49	4,547·50	3,812·36	....
	1163U	Two Chinamen	....	....	....	....	....	....	....	9·25	15·28	....
		Voided leases	....	....	....	....	....	....	3,881·18	7,349·00	8,409·85	10·54
		Sundry claims	....	....	....	....	....	2·16	932·23	1,983·75	2,648·51	....
Mulline	1107U	Ajax West	....	....	....	....	....	....	1·37	8,355·50	6,653·34	....
	1178U	Golden Wonder	....	....	60·50	80·49	....	....	....	60·50	80·49	....
	1173U	Riverina	....	....	138·00	16·66	....	....	....	167·50	40·17	....
	1176U	Wildcat	....	....	....	....	....	....	....	278·75	240·40	....
		Voided leases	....	....	....	....	....	....	274·09	135,810·07	117,394·26	530·82
		Sundry claims	....	....	10·00	28·11	....	10·82	296·42	11,205·64	9,909·60	1·10
Mulwarrie	1153U	Four Mile	....	....	13·50	147·90	6·22	....	....	106·50	688·05	6·22
	1113U	Oakley	....	....	200·00	1,205·39	250·27	....	....	4,802·00	8,019·00	333·95
		Voided leases	....	....	....	....	....	....	165·29	19,480·68	26,369·21	38·47
		Sundry claims	....	....	....	....	....	·80	282·29	3,106·33	2,722·13	....
Ularring	....	Voided leases	....	....	....	....	....	....	563·34	9,771·60	13,907·76	....
		Sundry claims	....	....	....	....	....	....	....	671·50	309·48	....
		From District generally :—										
		Sundry Parcels treated at :										
		Various Works	....	....	....	....	....	....	15·82	1,521·32	*33,793·18	12·68
		Reported by Banks and Gold Dealers	·14	....	....	·38	·01	112·95	424·28	100·00	106·72	·01
		Total	**·14**	**82·48**	**642·50**	**1,680·22**	**256·50**	**129·66**	**7,298·59**	**535,053·70**	**446,136·87**	**22,281·34**

NIAGARA DISTRICT.

Desdemona	....	Voided leases	....	....	....	....	....	....	7·12	9,809·00	7,555·81	12·04
		Sundry claims	....	....	....	....	....	....	10·35	2,225·45	892·48	....

Table I.—*Production of Gold and Silver from all sources, etc.*—**continued.**

Mining Centre	Number of Lease	Registered Name of Company or Lease	Total for 1964					Total Production				
			Alluvial	Dollied and Specimens	Ore treated	Gold therefrom	Silver	Alluvial	Dollied and Specimens	Ore treated	Gold therefrom	Silver
			Fine ozs.	Fine ozs.	Tons (2,240 lb.)	Fine ozs.	Fine ozs.	Fine ozs.	Fine ozs.	Tons (2,240 lb.)	Fine ozs.	Fine ozs.
		NORTH COOLGARDIE GOLDFIELD—*continued.*										
		ULARRING DISTRICT—*continued.*										
Kookynie	G.M.L. 928G	Altona	....	....	296·75	104·56	2·85	....	....	13,493·00	7,701·93	27·65
	911G	Cosmopolitan South	....	....	....	....	....	....	....	2,650·00	1,365·38	....
	940G	New Gladstone	....	....	....	....	....	....	....	381·25	69·03	·20
		Voided leases	....	....	....	....	....	3·35	347·30	745,952·71	394,988·56	5,376·87
		Sundry claims	....	....	....	....	....	60·92	106·60	9,462·80	6,960·91	4·19
Niagara	....	Voided leases	....	....	....	....	....	....	104·54	85,876·50	52,365·05	....
		Sundry claims	....	....	....	....	....	28·10	97·22	14,687·91	8,265·87	....
Tampa	....	Voided leases	....	....	....	....	....	....	41·58	50,477·57	23,287·71	174·24
		Sundry claims	....	....	....	....	....	32·60	283·40	8,041·33	4,113·02	....
	From District generally :—											
	Sundry Parcels treated at :											
	Various Works	....	....	....	....	....	....	....	....	1,220·50	*20,884·22	120·98
	Reported by Banks and Gold Dealers	....	·12	....	....	....	....	1,593·51	823·66	....	63·53	....
		Total	**·12**	....	**296·75**	**104·56**	**2·85**	**1,718·48**	**1,821·77**	**944,278·02**	**528,513·50**	**5,716·17**
		YERILLA DISTRICT.										
Edjudina	....	Voided leases	....	....	....	....	....	....	18·44	35,523·70	43,374·79	37·79
		Sundry claims	....	....	....	....	....	....	28·52	6,967·58	4,829·77	·69
Patricia	....	Voided leases	....	....	....	....	....	....	....	4,158·50	5,396·40	25·40
		Sundry claims	....	....	....	....	....	....	....	47·00	20·78	....
Pinjin	....	Voided leases	....	....	....	....	....	....	48·34	17,463·30	10,742·77	....
		Sundry claims	....	....	....	....	....	....	154·86	5,642·59	3,475·75	....
Yarri	G.M.L. 1347R	Dawn	....	....	48·00	3·93	....	....	....	138·50	22·96	....
	1320R	Margaret	....	....	77·00	8·92	....	....	....	4,683·00	1,327·51	·32
	1126R, etc.	Porphyry (1939) Gold Mines N.L.	....	....	....	....	....	....	....	66,939·00	9,893·51	261·95
		Prior to transfer to present holders	....	....	....	....	....	....	....	30,344·50	5,448·82	507·51
	1345R	Wallaby Extended	....	....	....	....	....	....	....	146·00	11·47	....
	1339R	Yilgangie	....	....	....	....	....	....	....	725·00	274·09	·46
		Voided leases	....	....	....	....	....	6·30	87·08	45,427·75	21,392·94	2·00
		Sundry claims	....	....	114·00	18·24	·13	·87	5·93	18,202·05	6,358·54	1·40
Yerilla	....	Voided leases	....	....	....	....	....	....	3,107·25	16,481·43	12,925·74	13·93
		Sundry claims	....	....	....	....	....	19·30	97·63	2,752·83	1,590·03	....

Yilgangie	1176R	Western Mining Corporation	....	....	1,702·00	1,187·73	165·94	....	....	32,859·50	30,520·91	4,469·37
		Prior to transfer to present holders	....	....	....	....	....	....	·85	1,244·75	1,830·28	....
		Voided leases	....	....	....	....	....	....	9·94	2,432·75	1,500·80	....
		Sundry claims	....	....	....	....	....	121·67	98·20	3,381·30	2,070·84	·63
		From District Generally :—										
		Sundry Parcels treated at :										
		State Battery, Yarri	....	....	....	....	....	....	....	276·50	..*9,060·18	11·65
		Various Works	....	....	....	....	....	2·17	....	642·25	*6,092·76	....
		Reported by Banks and Gold Dealers	·06	....	....	....	....	1,161·66	160·08	....	28·80	·09
		Total	**·06**	....	**1,941·00**	**1,218·82**	**166·07**	**1,311·97**	**3,817·12**	**296,479·78**	**178,190·44**	**5,333·19**

Broad Arrow Goldfield.

Bardoe	G.M.L. 2321W	Lady Grace	....	....	35·25	1·64	....	....	....	35·25	1·64	....
	2324W	Painted Doll	....	....	21·00	4·08	....	....	....	21·00	4·08	....
	2325W	Pride	....	....	37·25	235·16	....	....	....	37·25	235·16	....
		Voided leases	....	....	....	....	....	....	2,335·41	85,370·59	55,699·50	203·60
		Sundry claims	....	....	75·00	164·55	....	54·95	1,218·09	17,948·03	8,514·50	....
Black Flag	2229W	Bellevue	....	....	34·25	12·95	·16	....	212·68	4,136·48	3,256·47	9·92
	2320W	Bellevue South	....	....	41·50	58·02	3·40	....	....	41·50	58·02	3·40
	(2291W)	Bellevue South	....	....	51·00	25·79	1·97	....	....	150·75	37·40	2·04
		Voided leases	....	....	....	....	....	27·81	405·90	48,277·79	28,175·08	....
		Sundry claims	....	....	62·65	6·60	....	712·92	251·59	8,399·66	5,027·14	....
Broad Arrow	2314W	New Star	....	....	14·00	1·39	....	....	....	14·00	1·39	....
	2317W	Twist	....	....	11·00	6·03	....	....	....	11·00	6·03	....
		Voided leases	....	....	....	....	....	70·32	10,453·81	155,895·94	120,088·05	20·23
		Sundry claims	....	....	713·00	92·33	....	1,007·72	3,046·26	36,384·65	17,378·74	·48
Canegrass	....	Voided leases	....	....	....	....	....	....	27·77	669·82	460·72	....
		Sundry claims	....	....	....	....	....	....	227·55	717·45	505·06	....
Carnage	....	Voided leases	....	....	....	....	....	176·04	659·31	2,402·00	2,170·67	....
		Sundry claims	....	....	....	....	....	....	6·61	2,340·33	921·90	....
Cashmans	....	Voided leases	....	....	....	....	....	67·51	813·76	8,172·15	7,090·91	....
		Sundry claims	....	....	....	....	....	....	40·31	1,237·87	368·28	·05
Christmas Reef	2279W	New Mexico	....	....	....	....	....	....	....	673·75	494·90	6·99
	2253W	New Mexico South	....	....	....	....	....	....	....	3,352·25	3,534·94	·57
		Voided leases	....	....	....	....	....	....	55·49	1,865·12	3,606·65	....
		Sundry claims	....	....	....	....	....	....	441·85	3,330·64	3,249·25	....
Fenbark	....	Voided leases	....	....	....	....	....	....	4·42	6,771·00	2,711·68	....
		Sundry claims	....	....	....	....	....	....	51·96	3,031·52	1,000·47	....
Grant's Patch	2311W	Bent Tree	....	....	....	....	....	....	....	128·00	75·17	....
	2277W	Coronation	....	....	156·00	151·81	4·02	....	....	720·25	623·03	5·41
	2278W	Prince of Wales	....	....	247·25	266·41	6·23	....	....	1,007·50	1,610·05	47·11
	2277W, 2278W	(Ora Banda Amalgamated Mines N.L.)	....	....	....	....	....	....	1·53	973·55	1,155·07	·18
		Voided leases	....	....	....	....	....	....	274·13	204,083·59	80,144·60	175·00
		Sundry claims	....	....	48·50	6·39	....	....	356·66	7,401·59	3,238·65	....

Table I.—*Production of Gold and Silver from all sources, etc.*—continued

Mining Centre	Number of Lease	Registered Name of Company or Lease	Total for 1964					Total Production				
			Alluvial	Dollied and Specimens	Ore treated	Gold therefrom	Silver	Alluvial	Dollied and Specimens	Ore treated	Gold therefrom	Silver
			Fine ozs.	Fine ozs.	Tons (2,240 lb.)	Fine ozs.	Fine ozs.	Fine ozs.	Fine ozs.	Tons (2,240 lb.)	Fine ozs.	Fine ozs.
		BROAD ARROW GOLDFIELD—continued.										
Ora Banda	2270W, 2290W	Gimlet South leases	....	....	13,253·25	1,726·08	164·56	....	....	31,342·00	4,494·84	164·62
	2300W	Sleeping Beauty	....	....	250·00	43·81	....	....	....	3,250·00	992·43	1·14
		Voided leases	....	....	....	....	....	....	846·13	423,666·52	151,214·10	1,685·77
		Sundry claims	....	....	222·50	16·58	....	....	467·18	16,080·80	4,931·84	....
Paddington	2298W	Rona Lucille	....	....	51·50	80·66	....	....	....	279·00	121·12	....
		Voided leases	....	....	....	....	....	5,566·30	463·31	196,486·56	86,485·99	32·15
		Sundry claims	....	....	48·75	9·53	....	1,714·16	291·43	17,581·68	9,329·74	....
Riche's Find	2306W	Cave Hill	....	....	8·25	40·09	....	....	238·15	67·10	151·00	....
		Voided leases	....	....	....	....	....	....	21·64	7,643·09	6,095·69	71·36
		Sundry claims	....	....	37·50	7·32	....	....	549·09	2,081·50	2,516·94	·13
Siberia	....	Voided leases	....	....	....	....	....	1·07	2,649·28	28,995·47	31,776·06	....
		Sundry claims	....	....	....	....	....	289·06	1,261·72	21,324·59	12,893·43	....
Smithfield	2296W	Timewell	....	....	....	....	....	....	12·51	53·78	63·12	....
		Voided leases	....	....	....	....	....	....	19·19	11,717·71	2,068·58	....
		Sundry claims	....	....	....	....	....	....	124·29	3,969·59	14,00·01	·11
	From District generally :—											
	Sundry Parcels treated at :											
	State Battery, Ora Banda		....	....	....	*67·78	1·61	....	....	128·05	*26,955·32	75·38
	Various Works		....	....	....	....	....	2,275·66	1·24	17,048·27	*53,850·36	3,105·75
	Reported by Banks and Gold Dealers		2·06	....	....	....	....	10,026·99	165·70	61·68	95·83	·15
		Total	**2·06**	....	**15,419·40**	**3,025·00**	**181·95**	**21,990·51**	**27,995·95**	**1,387,379·66**	**746,881·60**	**5,611·54**

North-East Coolgardie Goldfield.

KANOWNA DISTRICT.

Mining Centre	Number of Lease	Registered Name of Company or Lease	Alluvial	Dollied and Specimens	Ore treated	Gold therefrom	Silver	Alluvial	Dollied and Specimens	Ore treated	Gold therefrom	Silver
Gindalbie	G.M.L. 1583X	S.H.E.	....	....	....	....	....	....	....	269·25	180·24	·10
		Voided leases	....	....	....	....	....	....	1,151·99	46,180·53	41,748·13	38·31
		Sundry claims	....	....	....	....	....	....	716·52	5,857·27	3,309·40	·01
Gordon	....	Voided leases	....	....	....	....	....	....	682·54	53,900·58	20,072·51	517·61
		Sundry claims	....	....	....	....	....	....	177·38	2,265·95	1,229·87	....
Kalpini	....	Voided leases	....	....	....	....	....	....	38·73	13,543·50	6,753·78	·07
		Sundry claims	....	....	....	....	....	24·70	269·72	1,492·50	1,026·37	....

Kanowna	1572X	Kanowna Red Hill	....	....	200·00	68·07	1·99	....	2·38	3,788·75	1,252·26	6·59
		Voided leases	....	....	....	....	....	24·94	4,516·76	685,625·60	380,504·87	2,482·24
		Sundry claims	....	....	29·25	56·52	....	125·32	2,169·07	28,480·07	12,176·54	1·71
Mulgarrie	....	Voided leases	....	....	....	....	....	....	1,216·63	6,902·26	4,197·98	....
		Sundry claims	....	....	....	....	....	....	16·78	1,290·00	646·60	....
Six Mile	....	Voided leases	....	....	....	....	....	....	1,603·72	559·00	767·72	....
		Sundry claims	....	....	....	....	....	....	56·51	771·75	232·66	....
	From District generally :—											
	Sundry Parcels treated at :											
		Various Works	....	....	....	....	....	330·42	867·52	158,935·05	*153,209·41	....
	Reported by Banks and Gold Dealers	....	....	....	....	....	....	106,033·45	40·42	·50	109·73	....
		Total	....	....	**229·25**	**124·59**	**1·99**	**106,538·83**	**13,526·67**	**1,009,862·56**	**627,418·07**	**3,046·64**

KURNALPI DISTRICT.

Jubilee	....	Voided leases	....	....	....	....	....	....	145·13	2,122·50	1,465·16	....
		Sundry claims	....	....	....	....	....	25·57	13·52	1,264·00	527·32	....
Karonie	G.M.L. 460K....	Consolidated Gold Mining Areas N.L.....	....	....	46·00	15·65	....	....	....	46·00	15·65	....
		Prior to transfer to present holder	....	....	....	....	....	....	....	152·00	84·12	....
		Sundry claims	....	....	....	....	....	....	....	132·50	60·80	....
Kurnalpi	....	Voided leases	....	....	....	....	....	371·18	3,166·80	4,130·76	4,022·13	6·27
		Sundry claims	....	....	25·50	7·20	....	324·12	727·39	4,601·61	2,371·03	....
Mulgabbie	457K	Mulgabbie Lucknow	....	....	....	....	....	....	....	70·00	6·72	....
		Voided leases	....	....	....	....	....	....	1,402·66	226·75	7,845·87	4·95
		Sundry claims	....	....	4·00	25·94	....	8·06	2,772·71	1,331·45	2,267·12	....
	From District generally :—											
	Sundry Parcels treated at :											
		Various Works	....	....	....	....	....	....	....	101·50*	388·63	....
	Reported by Banks and Gold Dealers	....	....	....	....	....	....	12,107·71	70·70	....	2·35	1·49
		Total	....	....	**75·50**	**48·79**	....	**12,836·64**	**8,298·91**	**14,179·07**	**19,056·90**	**12·71**

East Coolgardie Goldfield.

EAST COOLGARDIE DISTRICT.

Binduli	....	Voided leases	....	....	....	....	....	....	....	1,904·60	495·36	....
		Sundry claims	....	....	203·00	6·12	....	....	13·01	5,993·62	1,746·20	·08
Boorara	....	Voided leases	....	....	....	....	....	....	459·07	309,467·82	172,861·95	411·37
		Sundry claims	....	....	20·75	21·76	·18	·49	145·56	4,272·09	1,592·56	·23

Table I.—*Production of Gold and Silver from all sources, etc.*—continued.

Mining Centre	Number of Lease	Registered Name of Company or Lease	Total for 1964					Total Production				
			Alluvial	Dollied and Specimens	Ore treated	Gold therefrom	Silver	Alluvial	Dollied and Specimens	Ore treated	Gold therefrom	Silver
			Fine ozs.	Fine ozs.	Tons (2,240 lb.)	Fine ozs.	Fine ozs.	Fine ozs.	Fine ozs.	Tons (2,240 lb.)	Fine ozs.	Fine ozs.
		EAST COOLGARDIE GOLDFIELD—continued										
		EAST COOLGARDIE DISTRICT—*continued.*										
Boulder	G.M.L. 6145E....	Boomerang	....	....	....	....	....	....	....	77·00	8·00	....
	5531E	Cassidy's Hill	....	....	....	....	....	....	....	1,508·50	134·31	....
	5964E	Croesus Extended	....	....	....	....	....	....	....	192·75	16·57	....
	6537E	Golden Key	....	....	....	....	....	....	58·22	767·10	828·68	....
	5159E, etc.	Gold Mines of Kalgoorlie (Aust.) Ltd.	....	....	570,313·00	128,786·99	39,630·43	....	....	4,099,083·00	1,069,457·15	252,291·95
		Prior to transfer to present holders	....	....	....	....	....	....	791·73	15916155·97	6,415,881·49	819,123·27
	5695–5780E, 6254E	Great Boulder Proprietary Gold Mines Ltd.	....	....	425,292·00	111,414·90	52,635·23	....	1·53	15452155·97	6,751,584·95	1,690,515·06
	5478E, etc.	Lake View and Star Ltd.	....	....	683,488·00	165,435·39	19,867·27	....	....	18567005·30	5,349,637·31	594,288·88
		Prior to transfer to present holders	....	....	....	....	....	....	8·49	15792500·38	9,149,223·80	1,348,055·82
	5431E, etc.	North Kalgoorlie (1912) Ltd.	....	....	379,630·00	82,601·58	43,672·57	....	127·55	7,211,690·24	1,904,853·37	490,670·20
	5405E, etc.	North Kalgoorlie (1912) Ltd. (Croesus Pty. Group)	....	....	....	....	....	....	51·20	90,159·00	19,261·22	....
		Prior to transfer to present holders	....	....	....	....	....	43·99	....	4,018,629·01	2,815,959·95	97,625·03
		Voided leases	....	....	....	....	....	129·24	12,023·37	1,822,556·06	761,933·46	24,046·96
		Sundry claims	....	....	....	....	....	24·58	212·32	11,649·99	4,300·62	....
Cutters Luck	....	Voided leases	....	....	....	....	....	45·87	133·58	74·50	239·19	....
		Sundry claims	....	....	....	....	....	8·11	501·65	922·90	384·71	....
Feysville	....	Voided leases	....	....	....	....	....	....	110·93	863·30	425·16	....
		Sundry claims	....	....	22·50	2·92	....	....	199·00	1,374·75	662·75	....
Hampton Plains....	P.P.L. 175A, Loc. 48	S. Shackleton	....	....	98·00	30·94	·27	....	....	219·25	38·34	·27
	P.P.L. 476, Loc. 48	Ivy Rose	....	....	....	....	....	....	7·75	106·05	293·10	·72
	P.P.L. 478, Loc. 48	L. Bracegirdle	....	....	....	....	....	....	....	10·25	12·44	....
	P.P.L. 480, Loc. 48	C. Baxter	....	....	16·25	5·47	....	....	....	42·75	13·20	....
	Lease 1, Loc. 50	Western Mining Corporation Ltd.	....	....	4,151·00	361·62	86·37	....	....	4,151·00	361·62	86·37
	P.P.L. 277, Loc. 50	M. Africh	....	....	494·25	68·27	....	....	....	10,957·00	821·90	·01
	P.P.L. 277, Loc. 50	Pernatty	....	....	....	....	....	....	....	7,247·75	866·88	·01
	P.P.L. 277, Loc. 50	New Hope	....	....	....	....	....	....	17·23	61,468·55	11,175·94	....
	P.P.L. 280, Loc. 48	W. J. White	....	....	37·50	6·02	....	....	....	293·00	52·39	....
		Cancelled leases	....	....	....	....	....	4,585·24	241·51	305,565·62	86,770·64	5,906·26
		Sundry claims and leases	....	....	47·50	14·62	....	2·68	110·46	46,838·41	8,650·24	·13
Kalgoorlie	G.M.L. 6562E....	Bretvic	....	....	....	....	....	....	....	326·50	26·09	....

	6503E	Coronation	....	....	....	....	....	....	....	20·50	2·52	....
	5510E	Golden Dream	....	....	....	....	....	....	....	207·75	19·29	....
		Prior to transfer to present holders	....	....	....	....	....	....	....	530·74	149·77	....
	6636E	Golden Cross	....	....	71·00	4·11	....	....	....	71·00	4·11	....
	6620E	Golden Goose	....	....	60·50	2·85	....	....	....	60·50	2·85	....
	6502E	Gold Mines of Kalgoorlie (Aust.) Ltd. (Hannans North Mine)	....	....	2,894·25	531·02	3·25	....	....	9,971·75	2,207·51	7·56
		Prior to transfer to present holders	....	....	....	....	....	....	....	256·00	65·07	4·28
	6591E	Gold Mines of Kalgoorlie (Aust.) Ltd. (Kalgoorlie Star Mine)	....	....	10,712·00	831·89	....	....	....	10,712·00	831·89	....
		Prior to transfer to present holders	....	....	....	....	....	....	....	51·50	18·22	·57
	6563E, etc.	Gold Mines of Kalgoorlie (Aust.) Ltd. (Mt. Charlotte Mine)	....	....	120,450·00	16,216·18	....	....	....	125,197·00	16,693·78	....
		Prior to transfer to present holders	....	....	....	....	....	....	5·72	85,723·60	18,167·21	171·56
	6589E	Grays Central	....	....	22·00	11·92	....	....	....	844·75	165·07	....
	6091E	Lesanben	....	....	90·50	45·55	·95	....	193·96	1,238·30	790·65	3·88
	6485E	Maritana Hill	....	....	....	....	....	....	....	3,331·25	405·43	....
	6535E	Mary A	....	....	....	....	....	....	....	5,915·00	552·61	·14
	6615E	Middle Hannans	....	....	210·75	12·19	....	....	....	210·75	12·19	....
	6639E	Old Hinchcliffe	....	....	136·50	24·05	....	....	....	136·50	24·05	....
	5852E, (6024E)	Pedestal leases	....	....	....	....	....	....	....	1,828·50	490·37	....
	5852E	Pedestal	....	....	....	....	....	....	....	1,608·75	444·93	....
	(6024E)	Trident	....	....	....	....	....	....	....	58·75	36·67	....
		Voided leases	....	....	....	....	....	242·48	10,802·28	1,474,617·52	582,555·68	45,975·97
		Sundry claims	....	....	164·25	31·77	....	232·41	1,124·98	63,398·03	23,433·34	·18
Wombola	5689E, etc.	Haoma Leases	....	....	1,256·00	194·10	49·53	....	....	6,810·50	7,778·13	1,011·58
		Prior to transfer to present holders	....	....	....	....	....	....	·25	65,776·25	62,489·53	827·18
	5497E, 5500E....	Daisy Leases	....	....	1,291·00	1,151·40	69·68	....	....	20,600·95	18,813·63	858·72
	5497E	Daisy	....	....	....	....	....	....	....	6,282·25	5,031·93	....
	5500E	Happy-go-lucky	....	....	....	....	....	....	....	2,075·25	1,675·85	....
	6628E	Fred's Luck	....	....	239·50	23·81	·03	....	....	239·50	23·81	·03
	6635E	Hodad	....	....	2,786·00	329·74	49·51	....	....	2,786·00	329·74	49·51
	6312E	Inverness	....	....	164·50	21·04	....	....	....	3,566·50	631·04	....
	6487E	Leslie	....	....	....	....	....	....	....	382·25	355·13	·49
	6597E	Leslie North	....	....	810·00	68·40	13·41	....	....	810·00	68·40	13·41
	6614E	Logan's Gold Mine	....	....	486·25	91·02	1·25	....	....	616·75	109·86	1·25
	5798E	Maranoa	....	....	563·00	142·62	5·65	....	....	563·00	142·62	5·65
		Prior to transfer to present holders	....	....	....	....	....	....	32·17	3,183·50	1,633·27	....
	6533E	Rosemary	....	....	1,283·00	360·82	8·78	....	....	8,928·35	9,517·85	121·78
		Voided leases	....	....	....	....	....	3·80	2,498·57	34,993·09	44,556·63	1·18
		Sundry claims	....	....	183·50	25·56	....	....	711·10	26,113·43	14,588·86	·20
	From District generally :—											
	Sundry Parcels treated at :											
		State Battery, Kalgoorlie	....	....	....	*528·87	46·53	....	....	390·70	*37,768·94	396·18
		Sundry claims	....	....	....	....	....	11,014·57	465·61	5,440·46	2,541·10	....
		Various Works	....	....	....	....	....	384·36	64·70	41,135·02	*620,788·05	368,306·66
	Reported by Banks and Gold Dealers	....	1·85	....	....	64·65	....	17,003·72	10,073·32	415·68	7,569·00	....
		Total	**1·85**	....	**....2,207,688·25**	**509,470·16**	**156,140·89**	**33,721·54**	**41,186·82**	**85763329·85**	**36014058·12**	**5,740,780·58**

BULONG DISTRICT.

Balagundi	....	Voided leases	....	....	....	....	....	....	2,408·98	1,115·93	1,488·91	12·92
		Sundry claims	....	....	....	....	....	3·51	295·72	806·01	505·93	....

Table I.—*Production of Gold and Silver from all sources, etc.*—continued.

Mining Centre	Number of Lease	Registered Name of Company or Lease	Total for 1964					Total Production				
			Alluvial	Dollied and Specimens	Ore Treated	Gold Therefrom	Silver	Alluvial	Dollied and Specimens	Ore Treated	Gold Therefrom	Silver
			Fine ozs.	Fine ozs.	Tons (2,240 lb.)	Fine ozs.	Fine ozs.	Fine ozs.	Fine ozs.	Tons (2,240 lb.)	Fine ozs.	Fine ozs.
EAST COOLGARDIE GOLDFIELD—continued.												
BULONG DISTRICT.												
Bulong	G.M.L. 1311Y	Blue Quartz	....	....	....	....	....	....	....	2,031·25	701·61	....
	1341Y	John Curtin Central	....	....	113·00	5·58	....	....	....	113·00	5·58	....
		Voided leases	....	....	....	....	....	107·54	8,526·12	108,866·05	85,865·73	....
		Sundry claims	....	....	25·50	26·56	....	1,655·86	1,611·58	18,229·23	18,050·99	....
Hampton Plains	....	Voided leases	....	....	....	....	....	19·45	2·87	1,521·74	611·25	....
Majestic	....	Voided leases	....	....	....	....	....	....	63·91	1,021·95	386·97	....
		Sundry claims	....	....	....	....	....	42·88	154·58	1,926·58	959·78	....
Moreland's Find	....	Sundry claims	....	....	....	....	....	....	·13	308·75	81·84	....
Mt. Monger	....	Voided leases	....	....	....	....	....	....	2,771·39	1,437·85	1,256·10	....
		Sundry claims	....	....	....	....	....	215·60	....	379·05	308·48	....
Randalls	....	Voided leases	....	....	....	....	....	....	60·04	33,180·35	11,100·46	....
		Sundry claims	....	....	....	....	....	20·70	9·79	4,842·56	1,216·07	....
Taurus	....	Voided leases	....	....	....	....	....	2·06	3·70	1,765·10	909·84	....
		Sundry claims	....	....	....	....	....	112·69	51·88	2,656·60	1,049·81	....
Trans Find	....	Voided leases	....	....	....	....	....	....	....	1,098·42	876·22	....
		Sundry claims	....	....	....	....	....	....	5·93	728·25	315·06	....
	From District Generally :—											
	Sundry Parcels treated at :											
	L.T.T. 1536H.	Gold Mines of Kalgoorlie (Aust.) Ltd.	....	....	....	*479·57	86·52	....	....	....	*479·57	86·52
	Various Works		....	....	....	....	....	....	....	6,102·15	*6,675·38	....
	Reported by Banks and Gold Dealers		·09	....	....	....	....	25,225·22	70·15	·01	28·44	....
		Total	**·09**	....	**138·50**	**511·71**	**86·52**	**27,405·51**	**16,036·77**	**188,130·83**	**132,874·02**	**99·44**

Coolgardie Goldfield.

COOLGARDIE DISTRICT.

Mining Centre	Number of Lease	Registered Name of Company or Lease	Alluvial (1964)	Dollied and Specimens (1964)	Ore Treated (1964)	Gold Therefrom (1964)	Silver (1964)	Alluvial (Total)	Dollied and Specimens (Total)	Ore Treated (Total)	Gold Therefrom (Total)	Silver (Total)
Bonnievale	G.M.L. 5986	Jenny Wren	....	....	39·75	16·46	....	....	....	401·00	236·05	·29
	5622	Lucky Hit	....	....	....	....	....	....	3·28	1,146·35	676·78	....
	5890	Rayjax	....	....	46·25	57·33	1·09	....	....	660·75	1,106·27	4·70
	6007	Sabrina	....	....	14·50	11·07	....	....	....	38·75	31·34	....
		Voided leases	....	....	....	....	....	....	212·48	362,696·87	196,412·90	19·86
		Sundry claims	....	....	107·00	31·74	....	....	238·91	8,626·13	5,537·02	·87

Bulla Bulling	6003	Worked out	....	....	....	....	....	....	....	135·75	146·21	....
		Voided leases	....	....	....	....	....	....	....	1,410·56	968·52	....
		Sundry claims	....	....	....	....	....	5·21	15·98	2,068·76	819·66	....
Burbanks	....	Voided leases	....	....	....	....	....	14·90	376·98	420,591·86	306,446·31	521·06
		Sundry claims	....	....	53·00	13·85	....	55·05	497·55	17,480·35	9,279·94	·93
Cave Rocks	....	Voided leases	....	....	....	....	....	....	....	8,223·16	1,941·42	....
		Sundry claims	....	....	77·50	4·66	....	....	50·00	4,788·15	1,112·80	....
Coolgardie	(5935, etc.)	Gold Mines of Kalgoorlie (Aust.) Ltd.	....	....	238·00	51·19	2·63	....	166·69	145,899·50	73,000·23	910·06
	(5876)	Prior to transfer to present holders	....	....	....	....	....	....	....	6·25	2·22	....
	6000	Dendon	....	....	117·75	5·24	....	....	....	1,358·25	153·41	....
	6032	El Dorado	....	....	8·00	8·95	....	....	....	8·00	8·95	....
	5844	Jackpot	....	....	204·75	66·20	....	....	....	10,146·75	4,218·38	....
	5884	Lone Hand	....	....	....	....	....	....	19·85	499·00	84·85	....
	G.M.L. 6024	New Cock Shot	65·45	....	....	....	....	65·45	....	....	....	....
		Voided leases	....	....	....	....	....	1,301·71	5,297·85	1,112,278·44	450,852·97	4,820·20
		Sundry Claims	16·35	163·56	708·00	224·38	1·73	236·14	2,966·48	82,850·44	29,227·14	1·90
Eundynie	....	Voided leases	....	....	....	....	....	3·70	16·09	31,772·98	16,531·34	1·75
		Sundry claims	....	....	....	....	....	8·85	229·66	698·12	521·20	....
Gibraltar	5723	Lloyd George	....	....	....	....	....	....	....	763·00	176·78	....
		Voided leases	....	....	....	....	....	....	33·97	38,762·63	20,114·27	....
		Sundry claims	....	....	59·75	10·74	....	1·39	50·76	3,548·35	1,422·75	....
Gnarlbine	....	Voided leases	....	....	....	....	....	....	13·95	2,731·75	1,341·60	....
		Sundry claims	....	....	....	....	....	....	4·90	1,186·10	504·18	....
Hampton Plains	P.P.L. 17, Loc. 59	C. V. Avard	....	....	40·25	11·06	....	....	....	40·25	11·06	....
	P.P.L. 319, Loc. 59	Lady May	....	....	26·75	4·62	....	....	....	275·00	150·83	....
	P.P.L. 334, Loc. 59	Gold Mines of Kalgoorlie (Aust.) Ltd.	....	....	330·25	59·87	....	....	....	3,143·75	1,058·85	....
	P.P.L. 316, Loc. 59; P.P.L. 330, Loc. 59	Gold Mines of Kalgoorlie (Aust.) Ltd.	....	....	662·25	172·91	....	....	....	262,684·50	134,439·17	29,873·27
		Prior to transfer to present holders	....	....	....	....	....	....	....	9,346·75	5,081·22	....
	P.P.L. 448, Loc. 59	T. R. Baker	....	....	....	....	....	....	....	690·75	49·61	....
	P.P.L. 481, Loc. 59	C. W. Avard	....	....	....	....	....	....	....	115·00	82·38	....
	P.P.L. 482, Loc. 59	T. R. Baker	....	....	407·25	54·87	....	....	....	1,502·00	216·37	·08
	P.P.L. 486, Loc. 59	H. Boucher	....	....	216·50	43·25	....	....	....	423·50	96·42	....
	P.P.L. 487, Loc. 59	F. C. Bray	....	....	....	....	....	....	....	35·00	2·78	....
	P.P.L. 489, Loc. 59	C. L. Voumard	....	....	....	....	....	....	73·47	77·25	37·77	....
		Cancelled leases	....	....	....	....	....	2·56	486·33	17,516·21	13,010·93	1·10
		Sundry claims and leases	....	....	9·75	3·07	....	1·63	132·06	1,957·75	859·58	....

Table I.—*Production of Gold and Silver from all sources, etc.*—continued.

Mining Centre	Number of Lease	Registered Name of Company or Lease	Total for 1964					Total Production				
			Alluvial	Dollied and Specimens	Ore treated	Gold therefrom	Silver	Alluvial	Dollied and Specimens	Ore treated	Gold therefrom	Silver
			Fine ozs.	Fine ozs.	Tons (2,240 lb.)	Fine ozs.	Fine ozs.	Fine ozs.	Fine ozs.	Tons (2,240 lb.)	Fine ozs.	Fine ozs.
		COOLGARDIE GOLDFIELD—continued.										
		COOLGARDIE DISTRICT—*continued.*										
Higginsville	5647, 6002	Fairplay Gold Mine	....	....	30·00	3·41	....	....	62·70	28,676·75	3,195·11	·02
		Two Boys	....	....	14·75	10·61	....	....	....	809·00	255·82	·08
		Voided leases	....	....	....	....	....	....	482·47	45,601·85	22,058·79	160·72
		Sundry claims	....	....	....	....	....	....	187·25	3,721·76	1,963·41	....
Larkinville	....	Voided leases	....	....	....	....	....	22·77	54·44	2,335·16	3,256·49	....
		Sundry claims	....	....	....	....	....	....	147·20	490·53	1,033·19	....
Logans	6016	Great Lion	....	....	243·50	38·75	....	....	....	475·50	64·48	....
		Voided leases	....	....	....	....	....	....	11·09	106,660·81	26,931·68	....
		Sundry claims	....	3·90	....	....	....	6·88	132·85	3,385·10	1,055·96	....
Londonderry	....	Voided leases	....	....	....	....	....	....	95·04	34,155·35	22,238·37	·35
		Sundry claims	....	....	33·00	6·73	....	16·68	80·78	4,241·92	2,688·82	22·42
Mungari	....	Voided leases	....	....	....	....	....	....	17·71	1,872·50	458·43	....
		Sundry claims	....	....	129·25	11·03	....	1·77	153·24	3,082·69	772·59	....
Paris	5953, etc.	Paris Gold Mine Pty. Ltd.	....	....	....	1,573·75	3,108·71	....	....	42,516·00	14,187·89	15,299·39
	5873	(Paris West)	....	....	....	....	....	....	....	19·00	11·03	....
		Voided leases	....	....	....	....	....	·88	4·30	15,497·00	8,625·37	79·19
		Sundry claims	....	....	....	....	....	....	....	2,123·00	521·97	....
Red Hill	....	Voided leases	....	....	....	....	....	14·87	1,551·81	40,797·40	31,070·65	....
		Sundry claims	....	....	....	....	....	15·29	95·72	1,496·64	1,126·20	....
Ryans Find	5999	Little Nipper	....	5·56	26·00	88·13	....	....	1,107·00	65·50	441·27	....
		Voided leases	....	....	....	....	....	....	....	54·16	151·69	....
		Sundry claims	....	....	....	....	....	....	479·26	193·44	404·91	....
St. Ives	....	Voided leases	....	....	....	....	....	63·34	146·87	39,318·46	16,208·86	....
		Sundry claims	....	....	....	....	....	211·67	950·23	4,196·56	1,462·08	....
Wannaway	....	Voided leases	....	....	....	....	....	....	28·61	1,831·95	1,465·70	....
		Sundry claims	....	....	....	....	....	....	193·79	1,336·12	1,310·57	....
Widgiemooltha	5834	Harpers	....	....	....	....	....	....	9·54	40·00	93·06	....
	5451, etc.	Paris Gold Mines Pty. Ltd. (Host Group)	....	....	....	....	....	....	....	3,585·00	912·10	486·12
	5451	Host Group	....	....	....	....	....	....	12·75	1,604·15	565·02	....
		Voided leases	....	....	....	....	....	17·95	1,252·70	22,743·81	11,970·29	·17
		Sundry claims	....	....	....	....	....	46·49	470·06	16,230·66	6,895·15	·07

		From District generally :—										
		Sundry Parcels treated at :										
		State Battery, Coolgardie	....	....	....	*358·18	·60	....	....	771·01	41,372·24	17·73
		L.T.T. 1513H. G. M. Walsh	....	....	....	*635·83	164·59	....	....	....	*635·83	164·59
		L.T.T. 1516H. M. Knezevich	....	....	....	*21·62	....	....	....	....	*21·62	....
		L.T.T. 1537H. P. L. Short	....	....	....	*·23	....	....	....	....	*·23	....
		Various Works	....	....	....	....	....	7·75	....	4,375·61	*33,197·53	309·37
		Reported by Banks and Gold Dealers	3·82	2·86	....	....	....	14,999·28	742·26	48·25	141·36	1·05
		Total	**85·62**	**175·88**	**3,843·75**	**3,599·73**	**3,279·35**	**17,122·21**	**19,356·91**	**2,992,938·35**	**1,536,738·22**	**52,697·34**
		KUNANALLING DISTRICT.										
Carbine	G.M.L. 1048S	Carbine	....	....	....	....	....	....	....	33·50	17·79	....
		Voided leases	....	....	....	....	....	....	687·98	85,927·86	52,381·02	....
		Sundry claims	....	....	17·50	3·99	....	136·27	96·96	6,669·13	2,368·89	....
Chadwin	....	Voided leases	....	....	....	....	....	....	....	4,837·80	5,298·69	2·50
		Sundry claims	....	....	....	....	....	14·28	82·36	5,987·55	2,953·07	·25
Dunnsville	....	Voided leases	....	....	....	....	....	....	828·58	17,548·85	8,657·45	....
		Sundry claims	....	....	....	....	....	21·00	1,034·08	3,070·96	2,117·32	....
Jourdie Hills	....	Voided leases	....	....	....	....	....	....	18·00	28,009·74	19,401·09	28·45
		Sundry claims	....	....	20·50	9·77	....	1·86	49·81	2,057·50	927·29	1·05
Kintore	....	Voided leases	....	....	....	....	....	18·70	169·33	56,822·89	40,044·61	677·88
		Sundry claims	....	....	35·50	12·73	....	111·91	102·70	4,943·78	2,602·34	....
Kunanalling	1052S	Catherwood	....	....	234·50	10·44	....	....	....	234·50	10·44	....
		Voided leases	....	....	....	....	....	86·13	1,734·92	130,303·61	100,812·73	40·77
		Sundry claims	....	16·14	368·25	93·13	7·14	216·53	976·87	16,567·77	10,178·91	15·28
Kundana	....	Voided leases	....	....	....	....	....	....	....	465·00	68·12	....
		Sundry claims	....	....	....	....	....	....	....	475·25	60·38	....
		From District generally :—										
		Sundry Parcels treated at :										
		Gold Fields Aust. Development	....	....	....	....	....	....	....	....	*548·07	....
		Various Works	....	....	....	....	....	42·23	....	1,782·26	*5,063·55	....
		Reported by Banks and Gold Dealers	....	....	....	....	....	871·79	17·93	....	5·85	·49
		Total	....	**16·14**	**676·25**	**130·06**	**7·14**	**1,520·70**	**5,799·52**	**365,737·95**	**253,517·61**	**766·67**

Yilgarn Goldfield.

Blackbourne	....	Voided leases	....	....	....	....	....	....	....	1,282·50	341·37	....
		Sundry claims	....	....	....	....	....	....	....	392·50	81·15	....
Bullfinch	G.M.L. (3350, etc.)	Great Western Consolidated N.L. (Copperhead)	....	....	....	431·31	89·16	....	....	3,319,855·00	457,533·70	126,913·54
		Prior to transfer to present holders	....	....	....	....	....	....	64·80	78,404·34	24,644·88	....
		Voided leases	....	....	....	....	....	....	10·14	490,643·07	185,701·81	27,963·57
		Sundry claims	....	....	23·00	9·27	·84	8·47	45·49	7,616·89	4,165·98	14·93

Table I.—*Production of Gold and Silver from all sources, etc.*—continued.

Mining Centre	Number of Lease	Registered Name of Company or Lease	Total for 1964					Total Production				
			Alluvial	Dollied and Specimens	Ore treated	Gold therefrom	Silver	Alluvial	Dollied and Specimens	Ore treated	Gold therefrom	Silver
			Fine ozs.	Fine ozs.	Tons (2,240 lb.)	Fine ozs.	Fine ozs.	Fine ozs.	Fine ozs.	Tons (2,240 lb.)	Fine ozs.	Fine ozs.
						YILGARN GOLDFIELD—continued						
Corinthian	....	Voided leases	....	....	....	....	....	....	23·46	284,243·98	58,510·80	4,136·81
		Sundry claims	....	....	....	....	....	....	2·68	1,088·35	640·61	....
Eenuin	....	Voided leases	....	....	....	....	....	....	196·74	10,827·31	10,820·07	15·01
		Sundry claims	....	....	....	....	....	3·16	90·95	2,873·95	2,052·04	4·39
Evanston	....	Voided leases	....	....	....	....	....	....	79·27	64,533·06	37,402·13	974·56
		Sundry claims	....	....	....	....	....	4·98	....	638·35	159·55	....
Forrestonia	4506	Margaret Ellen	....	....	....	....	....	....	....	84·00	21·79	·70
		Voided leases	....	....	....	....	....	....	....	1,185·00	298·15	....
		Sundry claims	....	....	....	....	....	....	·49	578·75	285·71	8·47
Golden Valley	3266, etc.	Radio Leases	....	....	1,137·00	945·45	190·97	....	2·70	46,007·80	66,259·85	1,884·13
		Voided leases	....	....	....	....	....	....	36·34	40,367·92	29,278·11	29·54
		Sundry claims	....	....	....	....	....	4·58	241·60	6,679·07	4,950·53	2·34
Greenmount	....	Voided leases	....	....	....	....	....	45·99	21·62	125,905·64	31,667·08	961·19
		Sundry claims	....	....	....	....	....	·46	4·27	3,152·58	832·58	5·28
Holleton	4450	Brittania	....	....	....	....	....	....	....	2,200·00	1,726·15	....
		Voided leases	....	....	....	....	....	....	9·33	45,003·25	13,147·88	36·69
		Sundry claims	....	....	....	....	....	....	3·75	3,464·05	923·78	·20
Hopes Hill	4509	Hill View	....	....	....	....	....	....	....	35·00	2·01	·06
		Voided leases	....	....	....	....	....	....	74·78	314,574·67	63,026·25	4,364·39
		Sundry claims	....	....	....	....	....	21·12	9·575	4,708·27	1,463·61	1·20
Kennyville	3875	Victoria	....	....	....	....	....	....	....	5,458·00	1,206·32	2·12
		Voided leases	....	....	....	....	....	....	18·76	55,876·63	21,625·66	·59
		Sundry claims	....	....	....	....	....	....	5·06	8,720·50	2,346·84	·45
Koolyanobbing	....	Voided leases	....	....	....	....	....	....	·99	1,768·05	972·77	....
		Sundry claims	....	....	....	....	....	·26	17·33	724·85	339·23	....
Marvel Loch	4499	Bohemia	....	....	....	....	....	....	....	44·00	18·31	·98
	4434	Comwall	....	....	....	....	....	....	....	17,769·00	2,464·95	527·91
	4039	Cromwell	....	....	74·00	4·60	·07	....	....	1,069·50	164·51	·07
	3942, etc.	Edwards Reward Leases	....	....	1,693·75	340·99	....	....	....	75,726·75	32,480·80	399·11
		Prior to transfer to present holders	....	....	....	....	....	....	....	5,946·00	4,401·11	....
	4034	Firelight	....	....	42·00	3·49	·15	....	2·68	6,695·75	943·52	·15
	3724	Francis Firness	....	....	541·00	149·40	13·02	....	498·39	20,420·25	9,184·86	208·28
	4230	May Queen	....	....	....	....	....	....	....	286·00	43·42	....
	3970	Mountain Queen	....	....	43·50	5·69	·12	....	....	1,371·50	478·43	91·99
	4384	Newry	....	....	25·00	1·07	·04	....	....	6,086·75	715·79	97·38

	4419	Prince George	....	....	....	....	....	....	....	5,463·00	591·19	102·72
	4035	Undaunted	....	....	73·50	5·71	·07	....	....	938·50	119·30	·07
		Voided leases	....	....	....	....	....	....	1,546·04	1,203,164·08	276,900·97	15,851·24
		Sundry claims	....	....	103·00	7·66	·30	11·35	809·31	38,540·59	13,891·07	84·76
Mt. Jackson	....	Voided leases	....	....	....	....	....	....	180·85	55,166·78	39,927·52	2,313·77
		Sundry claims	....	....	....	....	....	6·44	52·87	10,935·95	4,879·54	70·74
Mt. Palmer	4250	Palmerston	....	....	....	....	....	2·03	1·69	591·50	103·33	·40
	4515	Speedie	....	....	230·50	13·94	·61	....	....	230·50	13·94	·61
		Voided leases	....	....	....	....	....	....	....	306,531·65	158,527·11	....
		Sundry claims	....	....	....	....	....	1,643·48	18·19	450·25	387·14	....
Mt. Rankin	4462	Golden View	....	....	....	....	....	....	316·90	142·00	284·87	2·38
	4469	Lynette	....	....	....	....	....	....	....	933·50	375·13	24·55
	4461	Marjorie Glen Reward	....	....	....	....	....	....	191·46	3,210·55	4,047·72	4·85
		Voided leases	....	....	....	....	....	3·84	5·20	6,058·37	975·23	....
		Sundry claims	....	....	....	....	....	....	1·85	771·00	956·57	....
Parkers Range	G.M.L. 4508	Buffalo	....	....	183·25	35·20	2·54	....	....	333·25	64·90	2·96
	4512	Constance Una	....	....	154·00	219·77	15·05	....	....	267·50	358·28	24·57
		Voided leases	....	....	....	....	....	·42	270·76	64,082·85	32,812·23	27·43
		Sundry claims	....	....	373·25	37·85	·92	6·59	303·93	13,659·55	5,648·68	2·27
Southern Cross	4424	Excelsior	....	....	....	....	....	....	....	166·00	17·19	1·14
	4081	Fraser's Central	....	....	....	....	....	....	....	11·25	12·49	1·54
	4510	Three Boys	....	....	....	....	....	....	....	·50	69·69	6·03
		Voided leases	....	....	....	....	....	4·89	261·35	892,896·93	313,894·18	20,274·78
		Sundry claims	....	....	62·25	15·22	1·24	95·90	648·99	8,648·41	2,747·28	7·90
Westonia	....	Voided leases	....	....	....	....	....	....	4·06	597,118·14	381,435·37	5,104·07
		Sundry claims	....	....	....	....	....	9·51	64·96	4,310·76	2,823·33	·72
	From District generally :—											
	Sundry Parcels treated at :											
	(L.T.T. 1528H). N. K. Ding		....	....	28·75	1·77	0·2	....	....	28·75	1·77	·02
	State Battery, Marvel Loch		....	....	60·00	*555·52	....	....	....	89·00	*2,653·35	3·06
	Various Works		....	....	....	....	....	....	....	595·98	*117,104·30	820·39
	Reported by Banks and Gold Dealers		·18	....	....	....	....	325·29	81·41	·60	170·54	....
		Total	·18	....	**4,847·75**	**2,783·91**	**315·12**	**2,198·76**	**6,807·19**	**8,279,646·52**	**2,435,118·30**	**213,289·00**

Dundas Goldfield.

Beete	G.M.L. 1908	Beete	....	....	....	....	....	....	....	694·50	530·89	22·99
	1907	Eldridge's Find	....	....	566·50	330·89	20·74	....	....	1,743·00	1,278·23	62·93
		Sundry claims	....	....	....	....	....	....	....	386·50	376·41	....
Buldania	....	Voided leases	....	....	....	....	....	....	3·02	846·05	708·99	....
		Sundry claims	....	....	....	....	....	....	39·25	1,324·27	861·36	·72
Dundas	....	Voided leases	....	....	....	....	....	1·88	28·02	6,241·98	2,560·53	155·02
		Sundry claims	....	....	....	....	....	·76	413·85	2,275·25	1,165·27	20·08

Table I.—*Production of Gold and Silver from all sources, etc.*—continued.

Mining Centre	Number of Lease	Registered Name of Company or Lease	Total for 1964					Total Production				
			Alluvial	Dollied and Specimens	Ore treated	Gold therefrom	Silver	Alluvial	Dollied and Specimens	Ore treated	Gold therefrom	Silver
			Fine ozs.	Fine ozs.	Tons (2,240 lb.)	Fine ozs.	Fine ozs.	Fine ozs.	Fine ozs.	Tons (2,240 lb.)	Fine ozs.	Fine ozs.
		DUNDAS GOLDFIED—continued.										
Norseman	1288, etc.	Central Norseman Gold Corporation N.L.	....	....	181,814·00	100,340·43	55,705·08	....	....	3,778,149·20	1,757,948·21	1,134,728·44
		Prior to transfer to present holders	....	....	....	....	....	....	1,663·32	69,819·83	47,892·08	16,508·85
	1315, etc.	Norseman Gold Mines N.L.	....	....	....	....	....	....	....	964,099·00	241,009·50	353,206·54
		Prior to transfer to present holders	....	....	....	....	....	....	....	20,657·00	3,909·60	4,981·00
		Voided leases	....	....	....	....	....	14·27	10,601·15	917,065·17	601,851·09	39,001·96
		Sundry claims	....	4·30	134·50	38·76	2·64	1,052·09	3,517·88	49,745·45	22,630·64	225·81
Peninsula	....	Voided leases	....	....	....	....	....	....	24·29	9,603·39	6,102·61	12·20
		Sundry claims	....	....	....	....	....	....	....	217·25	119·32	·97
	From District generally :—											
	Sundry Parcels treated at :											
	State Battery, Norseman		....	....	....	*149·89	3·47	....	....	427·89	*25,508·88	1,055·00
	Various Works		....	....	....	....	....	....	54·52	1,029·89	*15,124·31	2,588·91
	Reported by Banks and Gold Dealers		....	....	....	....	....	1,182·78	49·59	47·50	21·37	·70
		Total	....	**4·30**	**182,515·00**	**100,859·97**	**55,731·93**	**2,251·78**	**16,394·89**	**5,824,373·12**	**2,729,599·29**	**1,552,572·12**

Phillips River Goldfield.

Mining Centre	Number of Lease	Registered Name of Company or Lease	Alluvial (1964)	Dollied and Specimens (1964)	Ore treated (1964)	Gold therefrom (1964)	Silver (1964)	Alluvial (Total)	Dollied and Specimens (Total)	Ore treated (Total)	Gold therefrom (Total)	Silver (Total)
Hatters Hill	....	Voided leases	....	....	....	....	....	....	4·38	1,599·55	1,222·72	....
		Sundry claims	....	....	....	....	....	74·91	24·26	5,386·60	2,755·81	26·09
Kundip	G.M.L. 263	(Hillsborough)	....	....	....	....	....	....	....	258·00	65·75	19·33
		Voided leases	....	....	....	....	....	113·28	556·17	84,866·58	60,584·54	4,008·81
		Sundry claims	....	....	....	....	....	90·27	73·02	6,434·68	1,951·87	54·65
Mt. Desmond	....	Voided leases	....	....	....	....	....	....	1·40	9·00	3,905·46	6,891·5
		Sundry claims	....	....	....	....	....	....	....	80·00	41·96	51·01
Ravensthorpe	M.L. 411	Wehr Bros.	....	....	....	....	....	....	....	....	1·99	....
	M.C.S. 35, etc.	Ravensthorpe Copper Mines N.L.	....	....	....	§2,209·99	5,503·14	....	....	....	§14,282·01	41,953·01
		Voided leases	....	....	....	....	....	....	141·80	24,730·01	26,073·97	4,500·55
		Sundry claims	....	....	....	....	....	163·96	7·68	7,267·82	3,197·97	41·12
West River	....	Voided leases	....	....	....	....	....	....	....	....	10·34	31·06
		Sundry claims	....	....	....	....	....	....	....	....	6·60	3·44
	From District generally :—											
	Sundry Parcels treated at :											
	T.A. 11. F. E. Daw		....	....	....	....	....	....	....	....	*128·45	....
	Various Works		....	....	....	....	....	....	....	27·00	*4,118·73	515·43

		Reported by Banks and Gold Dealers	....	....	....	....	....	164·69	14·61	....	8·47	....
		Total	....	....	....	**2,209·99**	**5,503·14**	**607·11**	**823·32**	**130,659·24**	**118,356·64**	**58,096·09**

Northampton Mineral Field.

Northampton	....	Sundry leases and claims	....	....	....	....	....	....	....	....	....	†5,185·58
		Total	....	....	....	....	....	....	....	....	....	**†5,185·58**

South-West Mineral Field.

Burracoppin	....	Voided leases	....	....	....	....	....	....	....	710·85	706·38	....
		Sundry claims	....	....	15·50	23·44	....	....	·98	405·25	270·17	....
Donnybrook	....	Voided leases	....	....	....	....	....	23·24	....	1,613·30	816·23	....
		Sundry claims	....	....	....	....	....	44·01	43·03	119·50	15·71	15·18
Lake Grace	G.M.L. 117H	Griffins Find	....	....	....	....	....	....	....	294·00	154·39	....
		Sundry claims	....	....	54·00	63·53	....	....	....	81·75	81·44	....
Ongerup	103H	Hornblende	....	....	....	....	....	....	....	24·50	2·85	....
		Sundry claims	....	....	....	....	....	....	1·58	·33	1·74	....
	From Mineral Field generally :—											
		Miscellaneous voided leases and sundry claims	....	....	....	....	....	245·83	3·07	1,472·10	353·19	....
		Total	....	....	**69·50**	**86·97**	....	**313·08**	**48·66**	**4,721·58**	**2,402·10**	**15·18**

State Generally.

		Sundry Parcels treated at :										
		Various Works	....	....	....	....	....	....	....	27·00	*9,009·75	31,521·73
		Reported by Banks and Gold Dealers	2·09	....	....	....	....	1,191·97	1,110·71	....	967·53	1,140·93
		Total	**2·09**	....	....	....	....	**1,191·97**	**1,110·71**	**27·00**	**9,977·28**	**32,662·66**

TABLE II

Production of Gold and Silver from all Sources, showing in fine ounces the output, as reported to the Mines Department during the year 1964.

Goldfield	District	District						Goldfield					
		Alluvial	Dollied and Specimens	Ore Treated	Gold Therefrom	Total Gold	Silver	Alluvial	Dollied and Specimens	Ore Treated	Gold Therefrom	Total Gold	Silver
		Fine ozs.	Fine ozs.	Tons (2,240 lb.)	Fine ozs.	Fine ozs.	Fine ozs.	Fine ozs.	Fine ozs.	Tons (2,240 lb.)	Fine ozs.	Fine ozs.	Fine ozs.
Kimberley	....	....	....	....	....	....	....	....	....	60·00	15·42	15·42	....
West Kimberley	....	....	....	....	....	....	....	....	....	....	....	....	11,656·46
Pilbara	Marble Bar	190·01	....	1,252·00	728·14	918·15	89·98	216·44	2·64	1,422·00	748·60	967·68	90·48
	Nullagine	26·43	2·64	170·00	20·46	49·53	·50						
West Pilbara	....	....	....	....	....	....	....	....	....	....	....	....	....
Ashburton	....	....	....	....	....	....	....	1·15	....	....	....	1·15	....
Gascoyne	....	....	....	....	....	....	....	·36	·96	155·00	309·67	310·99	13·37
Peak Hill	....	....	....	....	....	....	....	....	18·34	....	....	18·34	·67
East Murchison	Lawlers	....	....	1,164·00	698·17	698·17	27·62	·42	....	1,343·00	846·96	847·38	41·13
	Wiluna	....	....	10·50	52·57	52·57	13·51						
	Black Range	·42	168·50	96·22	96·64	....	....						
Murchison	Cue	2·58	....	1,190·25	408·02	410·60	298·68	18·98	....	190,076·50	71,395·05	71,414·03	5,729·70
	Meekatharra	6·44	....	3,081·25	1,060·08	1,066·52	37·08						
	Day Dawn	9·89	....	180·25	59·13	69·02	5·71						
	Mt. Magnet	·07	....	185,624·75	69,867·82	69,867·89	5,388·23						
Yalgoo	....	....	....	....	....	....	....	·39	....	....	....	·39	....
Mt. Margaret	Mount Morgans	....	3·47	224·00	42·55	46·02	2·41	5·11	3·47	2,536·00	900·33	908·91	93·74
	Mount Malcolm	5·11	....	2,312·00	857·78	862·89	91·33						
	Mt. Margaret	....	....	....	....	....	....						
North Coolgardie	Menzies	·50	11·06	31,980·25	14,759·77	14,771·33	2,433·18	·82	93·54	34,860·50	17,763·37	17,857·73	2,858·60
	Ularring	·14	82·48	642·50	1,680·22	1,762·84	256·50						
	Niagara	·12	....	296·75	104·56	104·68	2·85						
	Yerilla	·06	....	1,941·00	1,218·82	1,218·88	166·07						
Broad Arrow	....	....	....	....	....	....	....	2·06	....	15,419·40	3,025·00	3,027·06	181·95
North-East Coolgardie	Kanowna	....	....	229·25	124·59	124·59	1·99	....	....	304·75	173·38	173·38	1·99
	Kurnalpi	....	....	75·50	48·79	48·79	....						
East Coolgardie	East Coolgardie	1·85	....	2,207,688·25	509,470·16	509,472·01	156,140·89	1·94	....	2,207,826·75	509,981·87	509,983·81	156,227·41
	Bulong	·09	....	138·50	511·71	511·71	86·52						
Coolgardie	Coolgardie	85·62	175·88	3,843·75	3,599·73	3,861·23	3,279·35	85·62	192·02	4,520·00	3,729·79	4,007·43	3,286·49
	Kunanalling	....	16·14	676·25	130·06	146·20	7·14						
Yilgarn	....	....	....	....	....	....	....	·18	....	4,847·75	2,783·91	2,784·09	315·12
Dundas	....	....	....	....	....	....	....	....	4·30	182,515·00	100,859·97	100,864·27	55,731·93
Phillips River	....	....	....	....	....	....	....	....	....	....	2,209·99	2,209·99	5,503·14
South-West Mineral Field	....	....	....	....	....	....	....	....	....	69·50	86·97	86·97	....
Northampton Mineral Field	....	....	....	....	....	....	....	....	....	....	....	....	....
State Generally	....	....	....	....	....	....	....	2·09	....	....	....	2·09	....
Outside Proclaimed Goldfield	....	....	....	....	....	....	....	....	....	....	....	....	....
Total	....	....	....	....	....	....	....	**335·56**	**315·27**	**2,645,956·15**	**714,830·28**	**715,481·11**	**241,782·81**

TABLE III

Return showing total production reported to the Mines Department, and respective Districts and Goldfields from whence derived, to 31st December, 1964.

Goldfield	District	District: Alluvial	District: Dollied and Specimens	District: Ore Treated	District: Gold Therefrom	District: Total Gold	District: Silver	Goldfield: Alluvial	Goldfield: Dollied and Specimens	Goldfield: Ore Treated	Goldfield: Gold Therefrom	Goldfield: Total Gold	Goldfield: Silver
		Fine ozs.	Fine ozs.	Tons (2,240 lb.)	Fine ozs.	Fine ozs.	Fine ozs.	Fine ozs.	Fine ozs.	Tons (2,240 lb.)	Fine ozs.	Fine ozs.	Fine ozs.
Kimberley	....	....	....	....	....	....	....	9,079·68	3,016·35	22,931·90	17,281·87	29,377·90	128·76
West Kimberley	....	....	....	....	....	....	....	1·30	24·68	1·00	2·49	28·47	25,231·75
Pilbara	Marble Bar	15,504·87	4,569·14	342,273·43	331,273·43	351,347·44	32,992·62	26,011·82	7,478·83	492,828·14	466,722·91	500,213·56	34,073·41
	Nullagine	10,506·95	2,909·69	149,974·42	135,449·48	148,866·12	1,080·79						
West Pilbara	....	....	....	....	....	....	....	6,339·37	374·74	24,900·96	24,317·02	31,031·13	1,910·66
Ashburton	....	....	....	....	....	....	....	9,268·52	482·46	6,807·10	2,913·43	12,664·41	41,971·38
Gascoyne	....	....	....	....	....	....	....	698·49	121·33	944·75	1,923·16	2,742·98	59·59
Peak Hill	....	....	....	....	....	....	....	3,378·79	5,319·22	781,766·73	322,689·99	331,397·00	3,790·50
East Murchison	Lawlers	7,103·38	2,343·19	2,015,093·17	824,230·99	833,677·56	27,230·47	9,010·82	22,207·27	12,620,199·33	3,651,792·55	3,683,010·64	60,275·37
	Wiluna	236·48	1,254·11	8,873,640·69	1,872,315·19	1,873,805·78	10,320·74						
	Black Range	1,670·96	18,609·97	1,731,456·47	955,246·37	975,527·30	22,724·16						
Murchison	Cue	5,124·31	9,104·99	6,814,862·81	1,402,490·43	1,416,719·73	274,684·74	25,664·90	59,174·57	14,533,203·12	5,800,909·16	5,885,748·63	504,866·67
	Meekatharra	14,650·23	18,260·03	2,314,561·81	1,309,789·78	1,342,700·04	5,234·28						
	Day Dawn	3,255·06	11,341·80	2,037,537·38	1,375,619·99	1,390,216·85	169,442·22						
	Mt. Magnet	2,635·30	20,467·75	3,366,241·12	1,173,008·96	1,736,112·01	55,505·41						
Yalgoo	....	....	....	....	....	....	....	1,808·77	3,223·19	443,349·58	264,036·39	269,068·35	1,522·41
Mt. Margaret	Mt. Morgans	3,571·23	9,361·98	1,217,920·31	717,948·09	730,921·30	5,830·73	11,781·75	35,425·32	11,497,891·52	4,961,425·33	5,008,632·40	262,795·13
	Mt. Malcolm	4,066·98	16,668·99	7,751,797·97	3,069,433·68	3,090,169·65	190,773·70						
	Mt. Margaret	4,143·54	9,354·35	2,528,173·24	1,174,043·56	1,187,541·45	66,190·70						
North Coolgardie	Menzies	1,693·82	7,029·59	1,890,546·58	1,407,801·82	1,416,525·23	35,173·84	4,853·93	19,967·07	3,666,358·08	2,560,642·63	2,585,463·63	68,504·54
	Ularring	129·66	7,298·59	535,053·70	446,136·87	453,565·12	22,281·34						
	Niagara	1,718·48	1,821·77	944,278·02	528,513·50	532,053·75	5,716·17						
	Yerilla	1,311·97	3,817·12	296,479·78	178,190·44	183,319·53	5,333·19						
Broad Arrow	....	....	....	....	....	....	....	21,990·51	27,995·95	1,387,379·66	746,881·60	796,868·06	5,611·54
North-East Coolgardie	Kanowna	106,538·83	13,526·67	1,009,862·56	627,418·07	747,483·57	3,046·64	119,375·47	21,825·58	1,024,041·63	646,474·97	787,676·02	3,059·35
	Kurnalpi	12,836·64	8,298·91	14,179·07	19,056·90	40,192·45	12·71						
East Coolgardie	East Coolgardie	33,721·54	41,186·82	85,768,309·85	36,014,058·12	36,088,966·48	5,740,780·58	61,127·05	57,223·59	85,956,440·68	36,146,932·14	36,265,282·78	5,740,880·02
	Bulong	27,405·51	16,036·77	188,130·83	132,874·02	176,316·30	99·44						
Coolgardie	Coolgardie	17,122·21	19,356·91	2,992,940·35	1,536,738·22	1,573,217·34	52,697·34	18,642·91	25,156·43	3,358,676·30	1,790,255·83	1,834,055·17	53,464·01
	Kunanalling	1,520·70	5,799·52	365,737·95	253,517·61	260,837·83	766·67						
Yilgarn	....	....	....	....	....	....	....	2,198·76	6,307·19	8,279,646·52	2,435,118·30	2,443,624·25	213,289·00
Dundas	....	....	....	....	....	....	....	2,251·78	16,394·89	5,824,373·12	2,729,599·29	2,748,245·96	1,552,572·12
Phillips River	....	....	....	....	....	....	....	607·11	823·32	130,659·24	118,356·64	119,787·07	58,096·09
South-West Mineral Field	....	....	....	....	....	....	....	313·08	48·66	4,721·58	2,402·10	2,763·84	15·18
Northampton Mineral Field	....	....	....	....	....	....	....	....	....	....	....	....	5,185·58
State Generally	....	....	....	....	....	....	....	1,191·97	1,110·71	27·00	9,977·28	12,279·96	32,662·66
Outside Proclaimed Goldfield	....												
Total	....	....	....	....	....	....	....	**335,605·78**	**313,701·35**	**150,057,147·94**	**62,700,655·08**	**63,349,962·21**	**8,669,965·72**

TABLE IV.

Total output of Gold Bullion, Concentrates, etc., entered for export and received at the Perth Branch of the Royal Mint from 1st January, 1886.

Year	Export	Mint	Total	Estimated Value
	Fine ozs.	Fine ozs.	Fine ozs.	£A
1886	270·17	....	270·17	1,147
1887	4,359·37	....	4,359·37	18,518
1888	3,124·82	....	3,124·82	13,273
1889	13,859·52	....	13,859·52	58,871
1890	20,402·42	....	20,402·42	86,664
1891	27,116·14	....	27,116·14	115,182
1892	53,271·65	....	53,271·65	226,284
1893	99,202·50	....	99,202·50	421,385
1894	185,298·73	....	185,298·73	787,099
1895	207,110·20	....	207,110·20	879,749
1896	251,618·69	....	251,618·69	1,068,808
1897	603,846·44	....	603,846·44	2,564,977
1898	939,489·49	....	939,489·49	3,990,697
1899	1,283,360·25	187,244·41	1,470,604·66	6,246,732
1900	894,387·27	519,923·59	1,414,310·86	6,007,610
1901	923,698·96	779,729·56	1,703,416·52	7,235,654
1902	707,039·75	1,163,997·60	1,871,037·35	7,947,661
1903	833,685·78	1,231,115·62	2,064,801·40	8,770,719
1904	810,616·04	1,172,614·03	1,983,230·07	8,424,226
1905	655,089·88	1,300,226·00	1,955,315·88	8,305,654
1906	562,250·59	1,232,296·01	1,794,546·60	7,622,749
1907	431,803·14	1,265,750·45	1,697,553·50	7,210,750
1908	356,353·96	1,291,557·17	1,647,911·13	6,999,881
1909	386,370·58	1,208,898·83	1,595,269·41	6,776,274
1910	233,970·34	1,236,661·68	1,470,632·02	6,246,848
1911	160,422·28	1,210,445·24	1,370,867·52	5,823,075
1912	83,577·12	1,199,080·87	1,282,657·99	5,448,385
1913	86,255·13	1,227,788·15	1,314,043·28	5,581,701
1914	51,454·65	1,181,522·17	1,232,976·82	5,237,352
1915	17,340·47	1,192,771·23	1,210,111·70	5,140,228
1916	26,742·17	1,034,655·87	1,061,398·04	4,508,532
1917	9,022·49	961,294·67	970,317·16	4,121,646
1918	15,644·12	860,867·03	876,511·15	3,723,183
1919	6,445·89	727,619·90	734,065·79	3,618,509
1920	5,261·13	612,581·00	617,842·13	3,598,931
1921	7,170·74	546,559·92	553,730·66	2,942,526
1922	5,320·16	532,926·12	538,246·28	2,525,812
1923	5,933·82	498,577·59	504,511·41	2,232,186
1924	2,585·20	482,449·78	485,034·98	2,255,927
1925	3,910·59	437,341·56	441,252·15	1,874,920
1926	3,188·22	434,154·98	437,343·20	1,857,715
1927	3,359·10	404,993·41	408,352·51	1,734,572
1928	3,339·30	390,069·19	393,408·49	1,671,093
1929	3,037·12	374,138·96	377,176·08	1,602,142
1930	1,753·09	415,765·00	417,518·09	1,864,442
1931	1,726·66	508,845·36	510,572·02	2,998,137
1932	3,887·07	601,674·83	605,561·40	4,403,642
1933	2,446·97	634,760·40	637,207·37	4,886,254
1934	3,520·40	647,817·95	661,338·35	5,558,873
1935	9,868·71	639,180·38	649,049·09	5,702,149
1936	55,024·58	791,183·21	846,207·79	7,373,539
1937	71,646·91	928,999·84	1,000,646·75	8,743,755
1938	113,620·06	1,054,171·13	1,167,791·19	10,363,023
1939	98,739·88	1,115,497·76	1,214,237·64	11,842,964
1940	71,680·47	1,119,801·08	1,191,481·55	12,696,503
1941	65,925·94	1,043,391·96	1,109,317·90	11,851,445
1942	15,676·48	832,503·97	848,180·45	8,865,495
1943	6,408·34	540,057·08	546,475·42	5,710,669
1944	1,824·99	464,439·76	466,264·75	4,899,997
1945	5,029·38	463,521·34	468,550·72	5,010,541
1946	6,090·14	610,873·52	616,963·66	6,640,069
1947	5,220·09	698,666·29	703,886·38	7,575,574
1948	4,653·72	660,332·07	664,985·79	7,156,909
1949	4,173·14	644,252·48	648,425·62	7,962,808
1950	4,161·53	606,171·88	610,333·41	9,466,270
1951	5,589·45	622,189·64	627,779·09	9,725,343
1952	9,608·62	720,366·44	729,975·06	11,847,917
1953	5,396·30	818,515·65	823,911·95	13,299,092
1954	3,089·08	847,451·09	850,540·17	13,313,618
1955	4,091·55	837,913·72	842,005·23	13,175,559
1956	2,331·10	810,048·68	812,379·78	12,705,581
1957	2,042·27	894,638·71	896,680·98	14,038,185
1958	1,810·69	865,376·80	867,187·49	13,554,934
1959	2,321·99	864,286·87	866,608·86	13,541,929
1960	2,068·66	853,690·02	855,758·68	13,371,661
1961	2,942·58	868,902·39	871,844·97	13,706,870
1962	4,539·02	854,829·18	859,368·20	13,435,730
1963	4,665·37	795,546·34	800,211·71	12,517,686
1964	3,070·91	709,776·09	712,847·00	11,149,943
	11,594,240·48	53,285,301·00	64,879,541·48	494,482,373

	1963	1964
	£A	£A
Estimated Mint value of above production	479,431,826	490,570,060
Overseas Gold Sales Premium distributed by Gold Producers Association, 1920–1924	2,589,602	2,589,602
Overseas Gold Sales Premium distributed by Gold Producers Association from 1952	1,311,002	1,322,711
Estimated Total	£A483,332,430	£A494,482,373
Bonus paid by Commonwealth Government under Commonwealth Bounty Act, 1930	161,448	161,448
Subsidy paid by Commonwealth Government under Gold Mining Industry Assistance Act, 1954, from 1955	4,921,321	5,463,022
Gross estimated value of gold won	£A488,415,199	£A500,106,843

TABLE V.

Quantity and Value of Minerals, other than Gold, Reported during the year 1964

Number of Lease, Claim or Area	Goldfield or Mineral Field	Registered Name of Producer	Quantity Long Tons	Metallic Content	Value £A
		ALUMINA (From Bauxite)	Alumina Recovered Tons		
M.L. 1SA	South-West	Western Aluminium N.L.	117,724·00	....	3,531,720·00 (f)
		ASBESTOS (Chrysotile)			
M.C. 98L, etc.	Pilbara	Stubbs, S. H.	463·69	....	42,158·00
L.T.T. 1454H	Pilbara	Hancock, L. G.	72·50	....	1,522·50
			536·19	....	43,680·50 (b)
		ASBESTOS (Crocidolite)			
M.C. 53, etc.	West Pilbara	Australian Blue Asbestos Ltd.	10,614·14	....	1,062,100·15 (b)
		BARYTES			
M.C. 20N	Murchison	Universal Milling Co. Pty. Ltd.	171·70	....	682·80 (a)
		BENTONITE (See Clays)			
		BERYL (g) (h)		BeO Units	
M.C. 304	Pilbara	White, A. L.	10·61	124·49	1,360·00
Crown Lands	West Pilbara	Sundry Persons	3·04	34·67	369·70
Crown Lands	Gascoyne	Sundry Persons	1·62	18·37	164·90
M.C. 27	Yalgoo	Todd, Dan and Breeze, B. F.	1·40	16·10	174·10
M.C. 34	Yalgoo	Palmer, L.	22·35	234·52	2,474·60
P.A. 2610	Yalgoo	Corney, R.	6·21	66·10	716·60
P.A. 2618	Yalgoo	McGlenchy, A. J. D.	1·28	15·81	174·00
P.A. 2621	Yalgoo	Fogarty, C. A.	·52	6·52	65·20
P.A. 2626	Yalgoo	Clinch, E. M.	·31	3·73	37·30
P.A. 2631	Yalgoo	Phillips, E. R.	7·18	76·25	729·55
M.L. 80, etc.	Coolgardie	Australian Glass Manufacturers Co. Pty. Ltd.	25·32	292·55	2,771·65
			79·84	889·11	9,037·60 (b)
		BUILDING STONE (Granite-Facing Stone)			
M.C. 680H	South-West	Crawford Quarries Pty. Ltd.	6·00	....	60·00
M.C. 719H	South-West	Crawford Quarries Pty. Ltd.	27·00	....	540·00
			33·00	....	(c) 600·00
		BUILDING STONE (Lepidolite)			
P.A. 7784	Coolgardie	Rowe, P.	8·35	....	(a) 73·00
		BUILDING STONE (Prase)			
M.C. 39	Coolgardie	Lefroy, G.	9·50	....	(a) 137·50
		BUILDING STONE (Quartz—Dead White)			
M.C. 59	Coolgardie	Lefroy, G.	115·00	....	(a) 865·00
		BUILDING STONE (Sandstone)			
M.C. 990H	South-West	Caporn, C. A.	62·00	....	186·00
M.C. 1036H	South-West	Caporn, C. A.	10·00	....	30·00
			72·00	....	(c) 216·00
		BUILDING STONE (Slate)			
M.C. 1020H	South-West	Gelfi, B. J.	50·00	....	(c) 300·00
		BUILDING STONE (Spongolite)			
Q.A. 1	Phillips River	Frayne, W. L.	771·00	....	(c)3,622·00
		CLAYS (Bentonite)			
M.C. 282H, etc.	South-West	Collins, A. C.	440·35	....	1,100·90
M.C. 437H, etc.	South-West	Noonan, E. J.	30·00	....	120·00
M.C. 907H, etc.	South-West	Universal Milling Co. Pty. Ltd.	205·93	....	350·00
			676·28	....	(a)1,570·90
		CLAYS (Cement Clays)			
M.C. 492H, etc.	South-West	Cockburn Cement Ltd.	18,410·00	....	23,013·00
M.C. 1016H	South-West	Swan Portland Cement Ltd.	1,324·00	....	884·00
M.C. 1019H	South-West	Bell Bros. Pty. Ltd.	7,616·00	....	4,093·00
			27,350·00	....	27,990·00 (c)

TABLE V.—*Quantity and Value of Minerals, other than Gold, Reported during the Year 1964—continued*

Number of Lease, Claim or Area	Goldfield or Mineral Field	Registered Name of Producer	Quantity Long Tons	Metallic Content	Value £A
		CLAYS (Fireclay)			
M.C. 304H, etc.	South-West	Clackline Refractories Ltd.	2,886·00	....	2,886·00
M.C. 522H, etc.	South-West	Bridge, J. S. & T. D.	17,490·00	....	24,631·70
M.C. 685H	South-West	Kargotich Bros.	8,100·00	....	6,000·00
M.C. 732H	South-West	Midland Brick Co. Pty. Ltd.	18,485·00	....	9,242·50
Private Property	South-West	Darling Range Firebrick Co.	290·50	....	276·00
			47,251·50	....	43,036·20 (c)
		CLAYS (Fuller's Earth)			
M.C. 452H	South-West	Read, D. J. and T. I.	114·00	....	(a) 456·00
		CLAYS (Kaolin)			
M.C. 247H	South-West	Universal Milling Co. Pty. Ltd.	61·35	....	(a) 137·50
		CLAYS (White Clay—Ball Clay)			
M.C. 19E	East Coolgardie	Gardiner, J. A.	22·00	....	66·00
M.C. 109H	South-West	H. L. Brisbane & Wunderlich Ltd.	548·00	....	2,192·00
			570·00	....	(c)2,258·00
		CLAYS (Brick, Pipe and Tile Clays)*			
M.C. 789H	South-West	Peters, O. V. and M. E.	4,000·00	....	5,000·00
Private Property	South-West	Stoneware Pipes and Tiles Pty. Ltd.	2,384·00	....	2,384·00
Private Property	South-West	Stoneware Pipes and Tiles Pty. Ltd.	462·00	....	423·70
Private Property	South-West	Stoneware Pipes and Tiles Pty. Ltd.	6,848·00	....	6,848·00
Private Property	South-West	Stoneware Pipes and Tiles Pty. Ltd.	21·00	....	21·00
Private Property	South-West	Swaby, F. W.	15,000·00	....	18,750·00
			28,715·00	....	(c)33,626·70
* Incomplete : Figures relate mainly to production reported from holdings under the Mining Act.					
		COAL			
C.M.L. 448, etc.	Collie	Griffin Coal Mining Co. Ltd.	581,982·70	....	1,181,785·40
C.M.L. 437, etc.	Collie	Western Collieries Ltd.	405,437·00	....	1,157,681·70
			987,419·70	....	2,339,467·10 (e)
		COPPER ORE AND CONCENTRATES (g) (h)			
				Copper Units	
M.C. 35, etc.	Phillips River	Ravensthorpe Copper Mines N.L.	4,324·93	106,886·00	268,648·20 (b)
Gold and Silver content transferred to respective Items.					
		COPPER (Metallic By-Product) ((g) (h) (j)			
				Copper Tons	
G.M.L. 5873, etc.	Coolgardie	Paris Gold Mines Pty. Ltd.	....	(h) * 46·14	(b) 7,229·70
* From 293·76 tons Gold/Copper concentrates reported. Gold and Silver content transferred to respective Items.					
		CUPREOUS ORE AND CONCENTRATES (Fertiliser)			
				Average Assay Cu.%	
P.A. 2730	Pilbara	Wilson, L. T.	10·19	14·10	316·45
M.C.	Pilbara	Henderson, J. R. & C. B.	21·43	12·10	545·20
M.C. 282L	Pilbara	Henderson, J. M., J. R., & C. B.	235·88	17·17	10,098·75
P.A. 845L	Pilbara	Criddle, J. E.	1·19	26·90	97·80
P.A. 853L	Pilbara	Weatherall, A.	·98	7·00	10·30
P.A. 857L	Pilbara	Henderson, I.	18·15	10·35	375·70
P.A. 859L	Pilbara	Henderson, J. M.	37·48	27·01	2,904·95
Crown Lands	Pilbara	Sundry Persons	22·99	7·45	269·95
Private Property	West Pilbara	Depuch Shipping and Mining Co. Pty. Ltd.	733·03	20·02	52,352·20
M.C. 240	West Pilbara	Cawse, L. W.	1·00	16·90	42·30
M.L. 259	West Pilbara	Lee, T.	35·42	14·80	1,188·35
M.C. 60	Ashburton	V. K. Taylor and Party	4·15	13·60	133·35
P.A. 350	Ashburton	Cummings, C. C.	5·90	18·99	292·10
P.A. 346	Ashburton	Nomads Pty. Ltd.	2·90	26·06	221·00
Crown Lands	Gascoyne	Sundry Persons	2·27	12·70	65·90
P.A. 3587N	Murchison	Lorne, N.	8·69	5·70	44·55
M.C. 15	East Murchison	Alac, M.	110·43	11·48	2,734·65
P.A. 1585	East Murchison	Sawyer, H. A.	13·82	10·42	289·90
P.A. 1586	East Murchison	James L. S. D.	25·24	10·91	574·25
M.L. 68P	Peak Hill	Thaduna Copper Mines Pty. Ltd.	673·00	19·20	42,708·00
M.L. 78P	Peak Hill	Motter, G.	12·50	16·00	515·00
M.C. 63P, etc.	Peak Hill	Parkinson, L. T.	44·13	11·95	1,663·50
M.C. 65P	Peak Hill	Lee, R.	30·87	25·53	2,773·90
M.C. 39	Yalgoo	O'Callaghan and Howlett	11·76	7·80	184·65
P.A. 2628	Yalgoo	Woosnam, H. G.	2·27	10·00	44·25
M.C. 6F	Mount Margaret	Alac, M.	34·44	11·94	903·70
M.L. 410	Phillips River	Kuzmins, W.	16·75	10·00	628·15
M.C. 35, etc.	Phillips River	Ravensthorpe Copper Mines N.L.	20·20	15·93	915·80
M.C. 41	Phillips River	Kuzmins, W.	30·00	12·91	1,452·30
Temp. Res. 2104H	Outside Proclaimed	United Aborigines Mission	29·63	20·04	1,678·05
			2,196·69	17·99	125,984·95 (a) (b)

TABLE V.—*Quantity and Value of Minerals, other than Gold, Reported during the Year 1964—continued*

Number of Lease, Claim or Area	Goldfield or Mineral Field	Registered Name of Producer	Quantity Long Tons	Metallic Content	Value £A
		FELSPAR			
M.L. 80, etc.	Coolgardie	Australian Glass Manufacturing Co. Pty. Ltd.	1,385·00	....	9,752·85
P.A. 7811	Coolgardie	Lefroy, G.	1·00	....	10·00
			1,386·00	....	(*a*)9,762·85
		FULLER'S EARTH (See Clays)			
		GLASS SAND			
M.C. 161H, etc.	South-West	Leach, L. J.	160·00	....	160·00
M.C. 285H, etc.	South-West	Leach, R. J.	520·00	....	780·00
M.C. 417H, etc.	South-West	Australian Glass Manufacturing Co. Pty. Ltd.	9,367·00	....	6,088·55
			10,047·00	....	(*c*)7,028·55
		GYPSUM			
M.C. 9, etc.	Yilgarn	West Australian Plaster Mills Pty. Ltd.	12,216·00	....	8,856·70
M.C. 30, etc.	Yilgarn	Ajax Plaster Co. Pty. Ltd.	9,632·00	....	7,945·00
M.C. 51, etc.	Yilgarn	H. B. Brady Co. Pty. Ltd.	12,272·00	....	15,343·50
M.C. 12, etc.	Dundas	McDonald and Whitfield	893·00	....	446·50
M.C. 25, etc.	Dundas	Garrick Agnew Pty. Ltd.	4,201·72	....	13,965·00
M.C. 485H, etc.	South-West	Swan Portland Cement Ltd.	2,238·00	....	1,955·00
M.C. 612H, etc.	South-West	Hewitt, B.	3,426·40	....	4,710·80
M.C. 881H	South-West	Dooka Gypsum Co.	119·00	....	556·00
			44,998·12	....	53,778·50 (*a*) (*b*)

Includes 4,201·72 tons for Export. Plaster of Paris reported as manufactured during the year being 21,942·00 tons from 31,327·00 tons of Gypsum by five Companies. Gupsum used in the manufacture of Cement = 8,769·00 tons.

Number of Lease, Claim or Area	Goldfield or Mineral Field	Registered Name of Producer	Quantity Long Tons	Metallic Content	Value £A
		IRON ORE—(Pig Iron Recovered)			
Temp. Res. 1258H	Yilgarn	Charcoal Iron and Steel Industry	Pig Iron Recovered Tons 47,906·00	....	1,101,608·00 (*c*) (*d*)

Ore treated 82,843 tons — Average Assay = 62·00% Fe

Number of Lease, Claim or Area	Goldfield or Mineral Field	Registered Name of Producer	Quantity Long Tons	Metallic Content	Value £A
		IRON ORE (For Export)			
M.L. 10, etc.	West Kimberley	Australian Iron & Steel Ltd.	1,280,864·00	Average Assay Fe% 63·12	1,270,189·00 (*b*)
		LEAD ORES AND CONCENTRATES (*g*) (*h*)			
M.C. 29	West Kimberley	Devonian Pty. Ltd.	3,354·17	Lead Content Tons 619·50 Zinc Content Tons 825·08	92,631·55 (*b*)
		* LIMESTONE (For Building and Burning Purposes)			
M.C. 532H	South-West	Gibbs, C. E. & A. J.	2,310·00	....	2,887·50
M.C. 575H, etc.	South-West	Susac, F. & Y.	4,800·00	....	6,000·00
M.C. 684H, etc.	South-West	Bell Bros. Pty. Ltd.	1,402·00	....	1,752·50
M.C. 692H, etc.	South-West	Franconi, D. & S.	16,694·00	....	23,847·00
M.C. 702H, etc.	South-West	Makrides, J.	110·00	....	220·00
M.C. 989H	South-West	Casella, S.; Casella, M.; Ioppolo, G. J.	5,398·00	....	6,747·50
			30,714·00	....	41,454·50 (*c*)

* Incomplete: Figures relate only to production reported from holdings under the Mining Act.

Number of Lease, Claim or Area	Goldfield or Mineral Field	Registered Name of Producer	Quantity Long Tons	Metallic Content	Value £A
		* LIMESTONE (For Agricultural Purposes)			
M.C. 50	Dundas	Esperance Lime Supply	199·00	....	398·00
M.C. 723H	South-West	Plozza, C. W. and W. A.	669·00	....	669·00
			868·00	....	(*c*)1,067·00

* **Incomplete: Figures relate only to production reported from holdings under the Mining Act.**

Number of Lease, Claim or Area	Goldfield or Mineral Field	Registered Name of Producer	Quantity Long Tons	Metallic Content	Value £A
		LIMESAND (For Agricultural Purposes)			
Private Property	South-West	Dooka Gypsum Co.	27·00	....	(*c*) 61·00
		LIMESHELL (For Agricultural Purposes)			
Private Property	South-West	Dooka Gypsum Co.	30·00	....	(*c*) 67·50
		LITHIUM ORES (Petalite) (*h*)			
				Li20 Units	
M.L. 80, etc.	Coolgardie	Australian Glass Manufacturers Co. Pty. Ltd.	208·00	873·60	(*a*)1,591·20
		LITHIUM ORES (Spodumene) (*g*) (*h*)			
				Li20 Units	
M.C. 161	Phillips River	Frayne, W. L.	51·54	313·88	(*b*)1,055·10
		MAGNESITE			
M.C. 76, etc.	Phillips River	Magnesite (W.A.) Pty. Ltd.	1,574·24	....	10,019·85 (*a*) (*b*)
		MANGANESE (Metallurgical Grade) (*g*)			
				Average Assay Mn%	
M.C. 268, etc.	Pilbara	Mt. Sydney Manganese Pty. Ltd.	32,444·81	50·57	386,795·95
M.C. 194L, etc.	Pilbara	Westralian Ores Pty. Ltd.	5,477·00	51·12	59,868·00
			37,921·81	50·65	446,663·95 (*b*)
		MANGANESE (Battery Grade)			
				Average Assay Mn02%	
M.L. 61P	Peak Hill	Westralian Ores Pty. Ltd.	304·00	70·00	(*a*)5,928·00
		MANGANESE (Low Grade)			
				Average Assay Mn%	
M.C. 24P, etc.	Peak Hill	Westralian Ores Pty. Ltd.	598·00	Not Known	(*a*)4,746·20
		MINERAL BEACH SANDS (Ilmenite) (*g*)			
				Average Assay Ti02%	
D.C. 56H, etc.	South-West	Cable (1956) Ltd.	42,620·90	54·70	See Footnote
D.C. 13H, etc.	South-West	Ilmenite Pty. Ltd.	28,325·00	54·75	
M.C. 619H, etc.	South-West	Westralian Oil Ltd.	75,746·00	58·83	
M.C. 516H, etc.	South-West	Western Titanium N.L.	177,326·80	55·24	
M.L. 389H, etc.	South-West	Western Mineral Sands Pty. Ltd.	6,814·00	53·60	
			330,832·70	55·92	1,538,175·40 (*b*)

Footnote: Current values for separate Companies not available for publication.

Number of Lease, Claim or Area	Goldfield or Mineral Field	Registered Name of Producer	Quantity Long Tons	Metallic Content	Value £A
		MINERAL BEACH SANDS (Monazite) (*g*) (*h*)			
				Th02 Units	
M.C. 619H, etc.	South-West	Westralian Oil Ltd.	714·00	4,742·60	29,151·00
M.C. 516H, etc.	South-West	Western Titanium N.L.	603·19	4,107·23	25,323·55
			1,317·19	8,849·83	54,474·55 (*b*)
		MINERAL BEACH SANDS (Rutile) (*g*) (*h*)			
				Ti02 Tons	
M.C. 516H, etc.	South-West	Western Titanium N.L.	825·51	794·54	25,770·60 (*b*)
		MINERAL BEACH SANDS (Leucoxene) (*g*) (*h*)			
				Ti02 Tons	
M.C. 619H, etc.	South-West	Westralian Oil Ltd.	129·50	102·80	2,011·00
M.C. 516H, etc.	South-West	Western Titanium N.L.	513·69	457·26	9,882·85
			643·19	560·06	11,893·85 (*b*)
		MINERAL BEACH SANDS (Zircon) (*g*) (*h*)			
				Zr02 Tons	
M.C. 619H, etc.	South-West	Westralian Oil Ltd.	3,802·00	2,486·88	39,304·00
M.C. 516H, etc.	South-West	Western Titanium N.L.	16,266·72	10,736·50	156,333·50
			20,068·72	13,223·38	195,637·50 (*b*)

TABLE V.—*Quantity and Value of Minerals, other than Gold, Reported during the Year* 1964—*continued*

Number of Lease, Claim or Area	Goldfield or Mineral Field	Registered Name of Producer	Quantity Long Tons	Metallic Content	Value £A
		OCHRE (Red)			
M.C. 26, etc.	Murchison	Universal Milling Co. Pty. Ltd.	323·51	....	(*a*)1,941·50
		PETALITE (See Lithium Ores)			
		PYRITES ORE AND CONCENTRATES (For Sulphur)		Sulphur Content Tons	
G.M.L. 5715E, etc.	East Coolgardie	Gold Mines of Kalgoorlie (Aust.) Ltd.	(*i*)23,885·00	7,498·28	93,728·58
G.M.L. 1460, etc.	Dundas	Norseman Gold Mines N.L.	(*i*)34,511·00	16,504·08	275,053·00
			58,396·00	24,002·36	368,781·58 (*a*)
		SILVER	Fine Oz.		
		By-Product Gold Mining	228,398·37	....	133,883·10
		By-Product Copper Mining	5,503·14	....	3,156·00
		By-Product Lead Mining	11,565·46	....	6,802·40
			245,557·97	....	143,841·50
		SPODUMENE (See Lithium Ores)			
		TALC			
Private Property	South-West	Three Springs Talc Pty. Ltd.	5,431·69	....	75,002·00 (*b*) (*c*)
		TANTO/COLUMBITE ORES AND CONCENTRATES (*g*) (*h*)		Ta205 Units	
M.C. 631	Pilbara	Trigg Hill Mining Syndicate	·08	4·30	135·00
Crown Lands	Pilbara	Sundry Persons	1·29	44·35	1,067·45
Crown Lands	Gascoyne	Sundry Persons	·04	1·30	35·65
M.C. 27	Yalgoo	Todd, Dan ; & Breeze, B. F.	1·39	91·09	3,358·25
M.C. 58, etc.	Greenbushes	Austin Bros.	(*k*) 3·83	161·59	3,817·40
M.L. 647. etc.	Greenbushes	Vultan Syndicate	(*k*) 7·94	239·53	4,873·75
			14·57	542·16	13,287·50 (*b*)
		TIN (*g*) (*h*)		Tons	
D.C. 53, etc.	Pilbara	Cooglegong Tin Pty. Ltd.	175·45	125·51	175,785·40
D.C. 201, etc.	Pilbara	Mineral Concentrates Pty. Ltd.	151·66	107·07	151,430·40
D.C. 254, etc.	Pilbara	Johnston, J. A. and Sons	122·77	87·67	124,114·20
D.C. 16, etc.	Pilbara	Leonard, H. L.	58·04	38·97	48,475·05
D.C. 276, etc.	Pilbara	D. D. Mining Co.	36·87	25·17	34,496·05
D.C. 654	Pilbara	Flegg, H. N.	·16	·09	107·25
D.C. 305	Pilbara	Russell, H. H.	4·62	3·17	3,942·90
M.C. 691, etc.	Pilbara	Edwards, M. R.	17·62	12·23	16,785·05
D.C. 474	Pilbara	Dorrington, A. W.	·51	·35	551·60
Crown Lands	Pilbara	Sundry Persons	11·06	7·62	9,249·35
Crown Lands	West Kimberley	Sundry Persons	·06	·04	49·55
M.C. 30	Coolgardie	Binnerinjie Tin Syndicate	·93	·62	1,021·20
M.C. 58, etc.	Greenbushes	Austin Bros.	36·19	23·40	30,884·60
M.L. 647, etc.	Greenbushes	Vultan Syndicate	20·87	14·36	23,324·85
M.C. 63	Greenbushes	Huitson, J.	·23	·14	173·40
			637·04	446·41	620,390·85 (*b*)
		TUNGSTEN ORES AND CONCENTRATES (Scheelite) (*g*) (*h*)		W03 Units	
L.T.T. 1252H	North Coolgardie	Linnett, A. S. & Hawkins, A. N.	2·42	172·91	605·65
P.A. 7765	Coolgardie	Short P. L., ...	1·89	138·63	568·00
			4·31	311·54	(*b*)1,173·65

(*a*) Value F.O.R. (*b*) Value F.O.B. (*c*) Value at Works. (*d*) Value of Mineral Recovered. (*e*) Value at Pit head. (*f*) Estimated Nominal Value ex Works. (*g*) Only results of shipments finalised during the period under review. (*h*) Metallic content calculated on assay basis. (*i*) Concentrates. (*j*) By-Product Gold mining. (*k*) By-Product Tin Mining.

TABLE VI—TOTAL MINERAL OUTPUT OF WESTERN AUSTRALIA

Recorded mineral production of the State to 31st December, 1964, showing for each mineral the progressive quantity produced and value thereof, as reported to the Department of Mines ; including Gold (Mint and Export) as from 1886, and Other Minerals as from commencement of such records in 1899.

Mineral		Quantity	Value
			£
Abrasive Silica Stone	tons	1·50	9·00
Alumina (From Bauxite)	„	370,784·00	(*f*)3,531,720·00
Alunite (Crude Potash)	„	9,073·05	215,864·72
Antimony Concentrates (*a*)	„	9,829·69	242,497·00
Arsenic (*a*)	„	38,674·08	747,205·00
Asbestos—			
Anthophyllite	„	509·35	6,773·71
Chrysotile	„	10,497·58	451,556·85
Crocidolite	„	131,722·23	14,667,830·25
Tremolite	„	1·00	25·00
Barytes	„	3,038·76	19,559·35
Bauxite (Crude Ore)	„	36,741·00	93,534·75
Beryl	„	3,606·33	467,160·74
Bismuth	lb.	12,384·00	3,770·30
Building Stone (*g*)—			
Chrysotile—Serpentine	tons	4·45	53·00
Granite (Facing Stone)	„	155·00	4,060·00
Lepidolite	„	8·35	73·00
Prase	„	9·50	137·50
Quartz (Dead White)	„	115·00	865·00
Sandstone	„	72·00	216·00
Sandstone (Donnybrook)	„	83·00	1,743·00
Slate	„	50·00	300·00
Spongolite	„	1,834·00	8,490·00
Calcite	„	5·00	25·00
Chromite	„	14,419·05	208,296·75
Clays—			
Bentonite	„	10,049·68	33,681·06
Brick, Pipe and Tile Clay (*g*)	„	135,946·00	146,542·10
Cement Clay	„	282,331·05	212,919·60
Fireclay	„	284,157·01	297,817·23
Fullers Earth	„	396·40	1,644·05
White Clay—			
Ball Clay	„	21,751·60	64,830·30
Kaolin	„	5,290·12	9,046·67
Coal	„	33,851,308·89	51,340,958·63
Copper Ore and Concentrates	„	287,112·96	3,386,740·65
Copper (Metallic By-Product) (*a*)	„	(*i*)191·50	32,687·55
Corundum	„	63·15	655·00
Cupreous Ore and Concentrates (Fertiliser)	„	81,462·57	1,379,719·65
Diamonds (*e*)	Carats	....	24·00
Diatomaceous Earth (Calcined)	tons	426·00	6,160·75
Dolomite	„	3,041·82	13,021·60
Emeralds (cut and rough)	carats	18,381·68	1,922·00
Emery	tons	21·15	375·00
Felspar	„	66,390·61	232,264·86
Fergusonite	„	0·30	391·40
Gadolinite	„	1·00	112·00
Glass Sand	„	116,759·51	84,076·16
Glauconite	„	(*h*)6,467·00	(*f*)150,384·50
Gold (Mint and Export)	fine ozs.	64,879,541·48	494,482,373·00
Graphite	tons	153·20	1,304·20
Gypsum	„	865,663·53	930,171·35
Iron Ore—			
Pig Iron Recovered	„	640,810·32	(*f*)8,445,400·06
For Export	„	9,961,820·00	9,878,057·69
For Flux	„	58,064·35	37,048·00
Jarosite	„	9·54	37·50
Kyanite	„	4,215·69	21,781·00
Lead Ores and Concentrates	„	470,917·58	4,877,019·95
Limestone (*g*)	„	215,248·51	152,340·50
Lithium Ores—			
Petalite	„	865·98	6,526·00
Spodumene	„	106·58	1,813·60
Magnesite	„	26,826·65	141,351·24
Manganese—			
Metallurgical Grade	„	662,941·11	8,623,531·71
Battery Grade	„	2,218·25	45,430·10
Low Grade	„	4,915·36	39,659·55
Mica	lb.	32,930·00	3,984·24
Mineral Beach Sands—			
Ilmenite Concentrates	tons	1,112,497·10	5,225,218·76
Monazite Concentrates	„	4,672·86	168,585·00
Rutile Concentrates	„	3,777·48	99,774·15
Leucoxene Concentrates	„	2,520·19	38,124·42
Zircon Concentrates	„	43,565·73	437,494·30
Crude Concentrates (Mixed)	„	155·95	766·50

TABLE VI.—Total Mineral Output of Western Australia—*continued*

Mineral		Quantity	Value
			£
Ochre—			
Red	,,	9,194·29	99,285·30
Yellow	,,	447·60	2,977·75
Phosphatic Guano	,,	11,842·06	72,560·45
Pyrites Ore and Concentrates (For Sulphur) (*b*)	,,	1,086,751·46	(*f*)6,403,991·35
Quartz Grit	,,	829·50	700·35
Semi-Precious Stones—			
Chalcedony	lb.	448·00	200·00
Chrysoprase	,,	5·00	5·00
Opaline	,,	25·00	3·75
Prase	,,	2,240·00	40·00
Tiger Eye Opal	,,	120·00	97·00
Sillimanite	tons	2·00	13·00
Silver (*c*)	fine ozs.	10,913,484·03	2,458,276·48
Soapstone	tons	565·40	1,927·85
Talc	,,	51,190·69	694,694·68
Tanto-Columbite Ores and Concentrates	,,	546·49	571,645·09
Tin	,,	21,365·51	4,311,887·15
Tungsten Ore and Concentrates—			
Scheelite	,,	167·36	69,897·62
Wolfram	,,	303·42	61,758·65
Vermiculite	,,	1,832·96	11,830·60
Zinc (Metallic By-Product) (*d*)	,,	408·40	1,990·07
Zinc Ore (Fertiliser)	,,	20·00	100·00
Total Value to 31st December, 1963		....	£626,489,425·24

(*a*) By Product from Gold Mining.
(*b*) Part By-Product from Gold Mining.
(*c*) By-Product from Gold, Copper and Lead Mining.
(*d*) By-Product from Lead Mining.
(*e*) Quantity not recorded.
(*f*) Value of mineral or concentrate recovered.
(*g*) Incomplete—being only production reports from holdings under the Mining Act.
(*h*) Mineral Recovered.
(*i*) Assayed Metallic Content.

Footnote.—Comprehensive mineral production records maintained in the Statistical Branch of the Department of Mines show locality, producers, period, quantity, assayed or metallic content, and value of the various minerals listed above.

TABLE VII.

SHOWING AVERAGE NUMBER OF MEN EMPLOYED ABOVE AND UNDER GROUND IN THE LARGER GOLDMINING COMPANIES OPERATING IN WESTERN AUSTRALIA DURING THE YEARS FROM 1955 TO 1964 INCLUSIVE.‡

COMPANY	1955			1956			1957			1958			1959			1960			1961			1962			1963			1964		
	Above	Under	Total	Above	Under	Total	Above	Under	Total	Above	Under	Total	Above	Under	Total	Above	Under	Total	Above	Under	Total	Above	Under	Total	Above	Under	Total	Above	Under	Total
†Boulder Perseverance, Ltd.	171	114	285	181	113	294	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Blue Spec Gold Mines, Ltd.	17	9	26	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Big Bell Mines Ltd	44	16	60	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Comet Gold Mines Ltd.	3	....	3	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Central Norseman Gold Corporation N.L.	166	225	391	159	209	368	165	226	391	166	232	398	173	214	387	169	209	378	163	220	383	151	213	364	151	208	359	157	181	338
Eclipse Gold Mines N.L.	....	....	....	....	....	....	....	....	....	27	8	35	17	10	27	17	15	32	18	13	31	16	9	25	13	6	19	2	4	6
Golden Horseshoe (New) Ltd.	39	....	39	35	....	35	6	....	6	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Gold Mines of Kalgoorlie (Aust.) Ltd. (Boulder)	257	192	449	228	223	451	417	500	917	392	538	930	374	455	829	375	446	821	374	430	804	379	436	815	426	449	875	378	379	757
Great Boulder Pty. Ltd.	359	379	729	349	380	729	330	400	730	323	387	710	308	399	707	290	385	675	296	385	681	300	369	669	307	378	685	306	381	687
*Great Western Consolidated	224	271	441	232	270	502	220	223	443	220	241	461	207	218	425	197	174	371	164	124	288	144	92	236	58	28	86	16	....	16
Hill 50 Gold Mine N.L.	82	73	155	98	85	183	108	94	202	103	103	206	95	88	183	97	87	184	97	93	190	99	110	209	98	130	228	100	143	243
†Kalgoorlie Enterprise Ltd.	7	101	108	8	100	108	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
§Kalgurli Ore Treatment Co. Ltd.	65	....	65	40	....	40	33	....	33	28	....	28	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Lake View and Star Ltd.	482	487	969	471	523	994	460	517	977	433	525	958	451	535	986	432	513	945	417	514	931	411	527	938	417	545	962	393	520	913
Moonlight Wiluna Gold Mines Ltd. (Timoni)	39	33	72	37	32	69	36	31	67	35	31	66	31	27	58	31	24	55	30	30	60	33	39	72	35	38	73	35	31	36
Mountain View Gold N.L.	3	1	4	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Gold Mines of Kalgoorlie (Aust.) Ltd. (Mt. Charlotte)	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	8	51	59
North Kalgurli (1912) Ltd.	95	236	331	156	239	395	158	250	408	163	263	426	181	251	432	181	249	430	187	246	433	208	243	451	212	249	461	214	254	468
Paris Gold Mines Pty Ltd.	....	....	....	....	....	....	....	....	....	....	....	....	6	4	10	15	11	26	20	17	37	28	21	49	22	16	38	....	....	....
Gold Mines of Kalgoorlie (Aust.) Ltd. (Barbara and Bayleys Leases)	79	95	174	37	73	110	34	61	95	23	48	71	19	36	55	18	37	55	18	36	54	15	28	43	9	13	22	....	....	....
New Coolgardie Gold Mines N.L. (Callion Leases)....	8	35	43	3	11	14	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Ora Banda Amalgamated Ltd.	....	2	2	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Radio Gold Mines	6	6	12	6	6	12	7	7	14	6	6	12	6	6	12	6	6	12	6	5	11	5	5	10	6	5	11	7	5	12
†South Kalgurli Consolidated	53	99	152	13	84	97	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Sons of Gwalia Ltd.	102	146	248	105	156	261	107	146	253	109	142	251	99	137	236	106	139	245	103	143	246	96	137	233	98	119	217	9	....	9
Sunshine Reward Amalgamated Leases	7	4	11	8	7	15	2	....	2	8	3	11	5	2	7	3	1	4	2	2	4	2	2	4	2	2	4	2	2	4
All other Operators	634	388	1,022	544	407	951	498	349	847	476	313	789	521	398	919	469	290	759	509	283	792	524	321	845	520	341	861	513	292	835
State Average (inc. Diggers)	2,933	2,912	5,845	2,710	2,918	5,628	2,581	2,804	5,385	2,512	2,840	5,352	2,493	2,780	5,273	2,406	2,586	4,992	2,404	2,541	4,945	2,411	2,552	4,963	2,374	2,527	4,901	2,140	2,243	4,383

* Including Copperhead, Frasers ,Nevoria, Corinthian and Pilot Groups

‡ Effective workers only and totally excluding non-workers for any reason whatsoever.

† Absorbed by Gold Mines of Kalgoorlie (Aust.) Ltd. from 1957

§ Absorbed by Gold Mines of Kalgoorlie (Aust.) Ltd. from 1959.

By Authority: ALEX. B. DAVIES, Government Printer