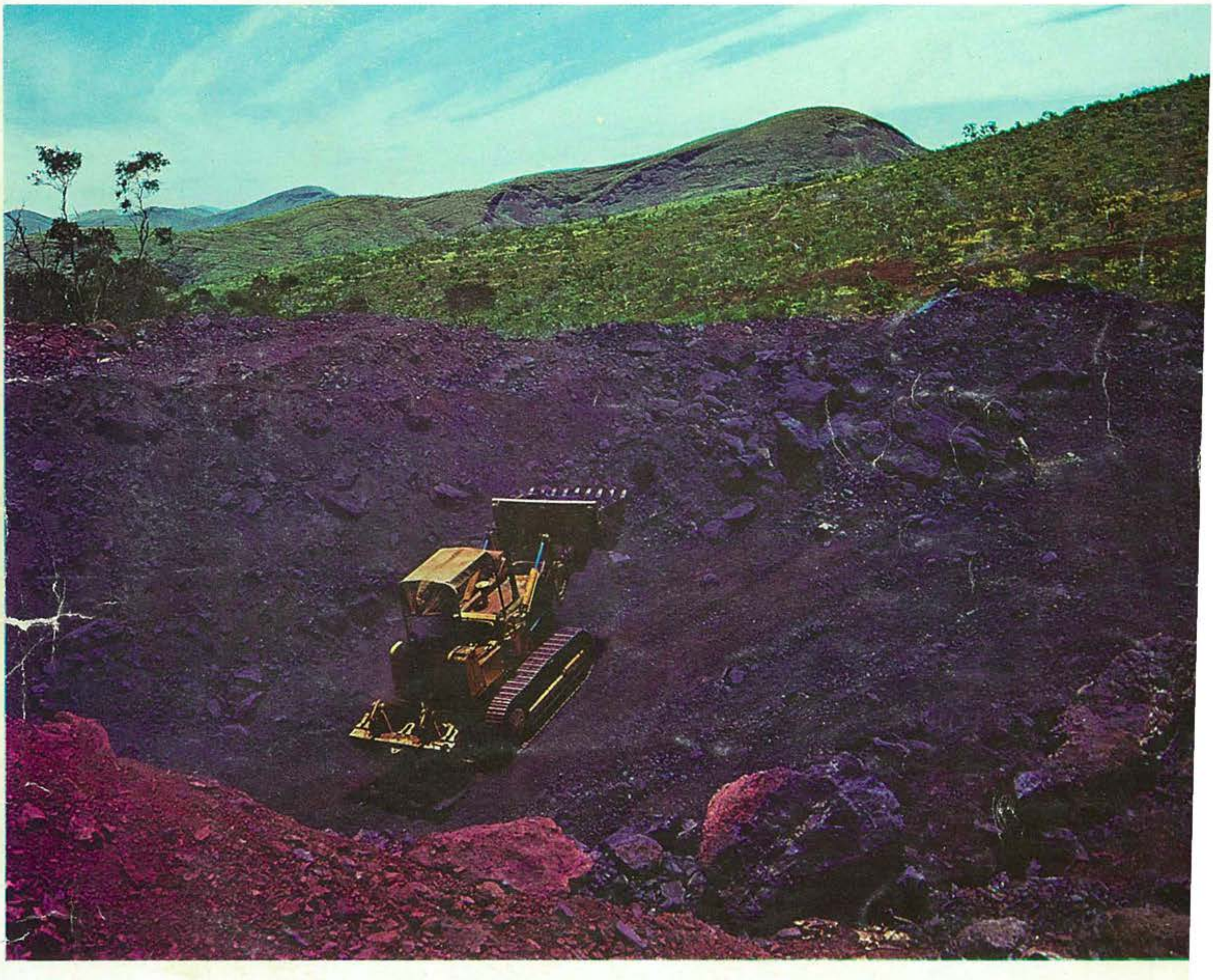
Mines Department Western Australia | 1965



Annual Report

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

REPORT OF THE DEPARTMENT *of* MINES WESTERN AUSTRALIA FOR THE YEAR 1965

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1966

25843

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 1965, 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,

I. R. BERRY,

Under Secretary for Mines.

Perth, 1966.

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WESTERN AUSTRALIA

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Report of the Department of Mines for the Year 1965

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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 1965.

The estimated value of the mineral output of the State for the year was £A26,912,693, an increase of £A2,161,287 in value compared with that for the preceding year and constitutes an all time record. This is 8.73 per cent. higher than the previous figure set in 1964.

The estimated value of gold received at the Perth Branch of the Royal Mint and exported in gold bearing material was £A10,361,082, a further decline of £A788,861 when compared with last year and equalled only 38.50 per cent of all minerals for 1965.

Other minerals realised: Alumina (from Bauxite), £4,454,040; iron ore (for export), £2,222,269; coal, £2,204,986; ilmenite, £1,926,188; manganese, £1,075,926; pig iron (from iron ore), £935,479; asbestos, £901,879; tin, £778,257; pyrites (for sulphur), £384,122; zircon, £375,134; limestone, £313,686; lead ores and concentrates, £196,319; clays, $175,443; silver, £170,206; copper ore and concentrates, £127,460; talc, £102,705; monazite, £52,151; cupreous ore and concentrates (fertiliser), £49,617; gypsum, £44,577; leucoxene, £10,806; felspar, £9,744; tanto/columbite ores and concentrates, £8,873; rutile, £7,994; building stone, £7,989; glass sand, £6,084; barytes, £3,003; lithium ores, £2,371; magnesite, £1,588; beryl, £1,445; ochre, £1,120; phosphatic guano, £150.

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

Coal production from Collie during the year showed a slight increase of 6,321 tons, although there was a decrease of 135,847 tons in the tonnage of deep mine coal. The overall average value per ton fell by 3.0d. per ton.

Figures for the last three years being:—

	1963	1964	1965
Tons	902,495	987,420	993,741
Total Value	£1,985,060	£2,339,467	£2,204,986
Average value per ton	43.990 sh.	47.385 sh.	44.377 sh.
Average effective workers	757	765	760
Proportion of deep mined coal	66.70%	65.23%	51.15%

Minerals other than Gold and Coal rose sharply in value to £14,346,625, an increase of £3,084,629 above last year to establish a new all time record, 27.39 per cent higher than the previous figure set in 1964. This was mainly due to increased values for Alumina (from Bauxite), Iron Ore (for export), Manganese, Ilmenite, Zircon and Tin.

Dividends paid by gold mining companies amounted to £1,181,047 a decline of £475,781 when compared with the previous year. (See Table 4, Part 2.)

To the end of 1965 the progressive total distributed by gold mining companies amounted to £73,789,283.

To the same date the progressive value of the whole mineral production of the State amounted to £653,401,916, of which gold accounted for £504,843,455. (See Table IV at back.)

Gold

The quantity of gold advised as being received at the Perth Branch of the Royal Mint (656,440.42 fine ounces), together with that contained in gold bearing material exported for treatment (2,996.56 fine ounces), totalled 659,436.98 fine ounces, which was 53,410 fine ounces less than the previous year. (See Table 1(a) Part 2.)

The total gold yield reported directly to the Department by the producers was 656,355 fine ounces, a decrease of 59,126 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 1965, viz. 2,530,165 tons, was 115,791 tons less than the previous year and constituted 58.95 per cent of the State record tonnage established in 1940.

The following tonnage increases were reported from the respective Goldfields—Peak Hill 1,304 tons, East Murchison 684 tons, Broad Arrow 216 tons, North-East Coolgardie 256 tons and Dundas 199 tons; those fields showing a reduction being Kimberley 60 tons, Pilbara 502 tons, Gascoyne 57 tons, Murchison 21,851 tons, Mt. Margaret 1,323 tons, North Coolgardie 5,473 tons, East Coolgardie 86,549 tons, Coolgardie 575 tons, Yilgarn 2,091 tons and South-West Mineral Field 69 tons.

The famous "Golden Mile" locality of Kalgoorlie-Boulder mining centres contained in the East Coolgardie Goldfield has to date treated 86.85 million tons of ore for 36.09 million fine ounces of gold (equivalent to 1,104.94 tons of the precious metal itself), valued at a progressively estimated £281.92 million. These figures represent 56.26 per cent of the States reported ore tonnage and 56.39 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.

East Coolgardie Goldfield with an ore treatment output of 2,121,278 tons showed a decrease of 86,549 tons. The decline was attributed to decreased tonnages treated by Gold Mines of Kalgoorlie (Aust.) Ltd. from main leases of 100,139 tons, Great Boulder Mines Ltd. 37,308 tons, Lake View and Star Ltd. 63,816 tons and North Kalgurli (1912) Ltd. 15,069 tons. The tonnage of ore treated by Gold Mines of Kalgoorlie (Aust.) Ltd. from their highly mechanised low grade group at Mt. Charlotte increased by 152,377 tons. Although the average grade of ore treated from the East Coolgardie Goldfield declined from 4.620 to 4.506 dwts. per ton, slight increases were shown in the average grade of ore treated by Gold Mines of Kalgoorlie (Aust.) Ltd. from their main leases and their Mt. Charlotte group and by Lake View and Star Ltd. Slight decreases in the grade of ore treated were shown by Great Boulder Gold Mines Ltd. and North Kalgurli (1912) Ltd.

In the Dundas Goldfield 182,714 tons of ore were treated which virtually equalled the tonnage treated in the previous year. Central Norseman Gold Corporation N.L. which treated practically the whole tonnage from the Dundas Goldfield showed a slight decline in the average grade of ore from 11.038 to 10.418 dwts, per ton.

The Murchison Goldfield showed a decrease of 21,851 tons of ore treated and 15,937 fine ounces in gold production. The decline was mainly attributed to decreased production by Hill 50 Gold Mine N.L. The Company's grade of ore treated also dropped to 6.587 dwts. per ton from the previous years average of 7.510 dwts. per ton.

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

The larger companies continue to experience a considerable difficulty under such adverse conditions in proving and maintaining sufficiently payable reserves to preserve the life-span of their mines. The employment problem has been further aggravated by the continued diversion of prospective labour to other industries. With the static price of gold the gold mining industry finds it difficult to compete on equal terms for labour with companies that can pass on higher wages costs, or with other organisations that are prepared to pay substantial premiums on wages in order to fulfil contractual obligations.

West Australian gold included in sales on open dollar markets by the Gold Producers' Association Ltd. for the period from July 1964 to June 1965, totalled 684,750.56 fine ounces; the extra premium received therefrom in excess of Mint Value amounted to £57,380 an overall average of 20.111 pence per fine ounce. This amount, less expenses, was distributed to the producer members during the year and approximated 19.306 pence per fine ounce.

Subsidy payments made by the Commonwealth Government during the year under the Gold Mining Subsidy Act, 1954-1962, totalled £829,581 an increase of £287,879 in comparison with the previous year. Of the amount distributed, £800,975 went to Large Producers, and £28,606 to Small Producers in this State.

COMPARATIVE MINERAL STATISTICS.

——	1964	1965	Variation
GOLD—			
Reported to Department (Mine Production)—			
Ore (tons)	2,645,956	2,530,165	115,791
Gold (fine ounces)	715,481	656,355	59,126
Average Grade (dwts. per ton)	5.408	5.188	0.220
Persons Engaged—			
(a) Effective Workers (excluding absentees)	4,383	4,094	— 289
(b) Total Pay Roll	4,785	4,468	— 317
Dividends (£A)	1,656,828	1,181,047	— 475,781
Mint and Export (Realised Production)—			
Gold (fine ounces)	712,847	659,437	— 53,410
Estimated Value (£A) (including Overseas Gold Sales Premium)	11,149,943	10,361,082	— 788,861
COAL—			
Reported to Department (Mine Production)—			
Tons	987,420	993,741	+ 6,321
Value (£A)	2,339,467	2,204,986	— 134,481
Persons Engaged—			
Effective Workers (excluding absentees)	765	760	— 5
OTHER MINERALS—			
Reported to Department—			
Value (£A)	11,261,996	*14,346,625	+3,084,629
Persons Engaged—			
Effective Workers (excluding absentees)	1,870	1,892	+ 22
TOTAL ALL MINERALS—			
Value (£A)	24,751,406	26,912,693	+2,161,287
Persons Engaged—			
Effective Workers†	7,018	6,746	— 272

* All time record.

† Excluding Oil Search Men which engaged an average of 257 men in the field in 1964 and 351 men in the field in 1965.

PART 2—MINERALS.

During the year royalty totalling £225,077 as against £184,039 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 temporarily suspended on Copper and Lead.

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

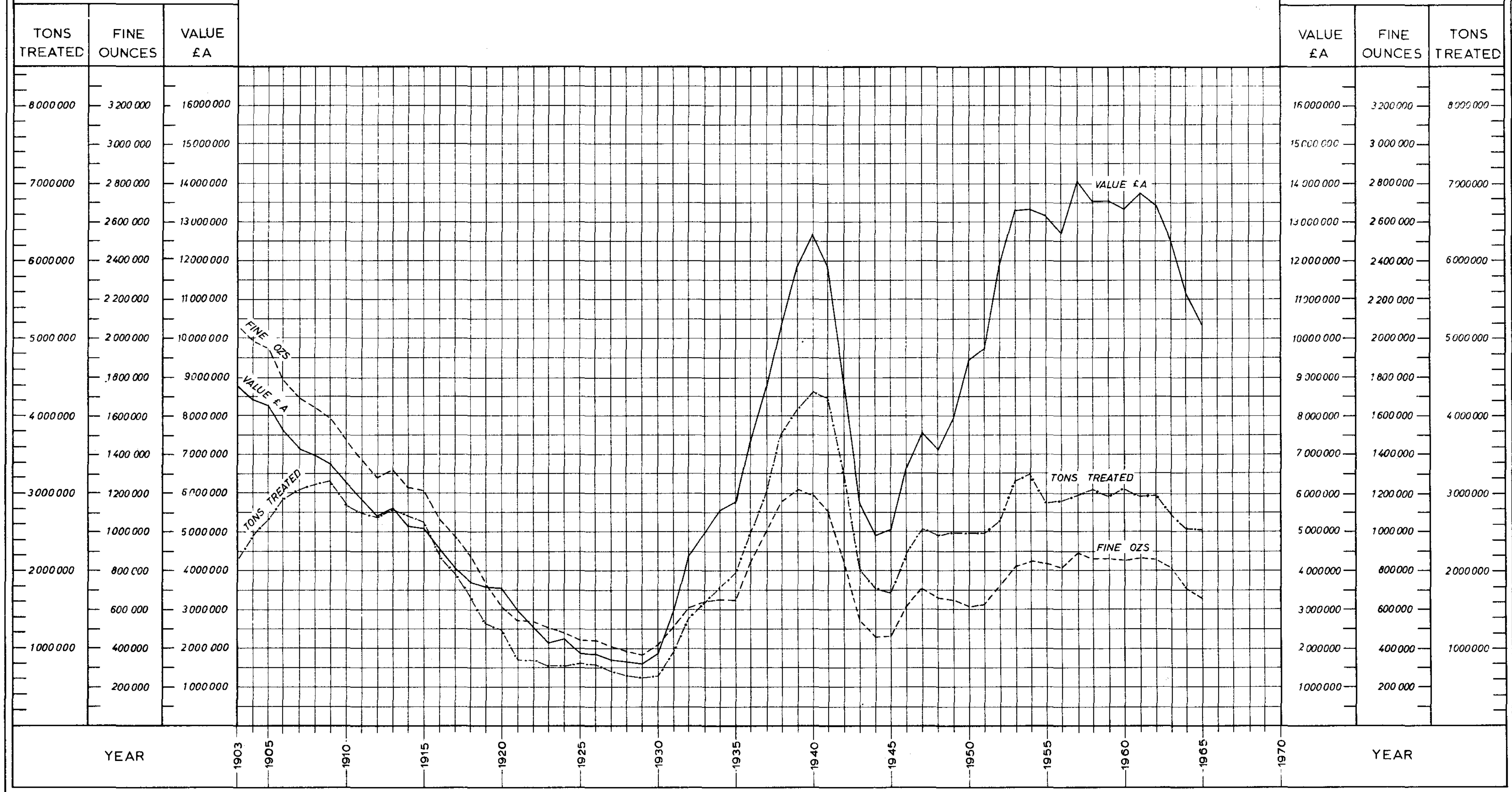
Particulars for the year are shown hereunder:—

Mineral	Amount Per Ton s. d.	Royalty Collected. £ s. d.
Asbestos	1 6	606 19 8
Barytes	6	18 12 0
Bauxite	9	17,657 11 11
Bentonite	6	13 5 0
Beryl	2 0	1 6 0
Building Stone	1 0	32 12 0
Clay	6	1,408 3 6
Coal	3	11,178 5 3
Felspar	6	22 11 0
Glass Sand	6	224 11 6
Gypsum	6	1,020 14 0
Ilmenite	1 0	12,716 3 0
Iron Ore	1 6	168,070 8 6
Leucoxene	1 0	16 1 6
Limestone	6	731 10 6
Magnesite	1 6	18 11 6
Manganese	1 6	7,294 9 2
Monazite	*	188 14 11
Ochre	6	12 10 6
Petalite	1 0	9 18 0
Pyrites	1 0	2,869 2 0
Rutile	1 6	11 5 0
Tanto/Columbite	*	72 19 9
Tin	2 0	67 6 0
Zircon	1 0	813 15 9
	Total:	£225,077 7 11

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

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



Iron ore production commenced from Koolan Island early in 1965 and the addition of just over one million tons shipped from this Island by the end of the year, lifted B.H.P. output from Yampi Sound by 75% to nearly 2¼ million tons for the twelve months.

Development of the Koolanooka, Mt. Goldsworthy and Mt. Tom Price iron ore deposits proceeded during the year to prepare these mines for production in 1966. Good progress was also made in construction of railways, townsites, offices, workshops and plants for these three projects, while deepening of Port Hedland for Mt. Goldsworthy shipments and establishment of the new port of Dampier at King Bay for Mt. Tom Price ore, were well advanced by the end of the year.

It is anticipated that more than six million tons of iron ore will be exported in 1966.

Alumina production from Darling Range bauxite continued to increase at the Western Aluminium N.L. plant at Naval Base and reached 148,468 tons worth £4,454,040. This was £922,320 more than the value of the 1964 production.

Substantial increases over the 1964 production were also reported in manganese and ilmenite. The value of the former rose £618,588 to £1,075,926 in 1965 while that of ilmenite was £388,013 higher than the previous year.

Increases in other minerals, notably tin and zircon were offset by decreases in production of asbestos and copper ore, the values of which declined by £189,060 and £141,188 respectively. Exploration and development programmes in regard to asbestos at Wittenoom Gorge and copper at Ravensthorpe are continuing.

Considerable interest was shown in the possibilities of nickel in the Eastern Goldfields and during the year several companies commenced comprehensive prospecting programmes to search for this mineral.

COAL.

Despite the loss of production from the Hebe mine which was flooded by an inrush of water in April the total tonnage of coal produced in 1965 rose by 6,321 tons to 993,740 tons.

The additional tonnage required to offset the Hebe loss was obtained by increased production from the Muja open-cut.

OIL.

Encouraged by oil and gas discoveries at and on Barrow Island, the search for oil continued with particularly intensive exploration to delineate and evaluate the Barrow Island discovery. Results of this indicated the presence of a large oil-bearing area, confirmed in May, 1966 as Australia's third and biggest commercial oil field.

Following agreement between the States and the Commonwealth regarding the search for oil in the offshore continental shelf areas, drafting of suitable legislation to regulate the issue of exploration and production titles was well advanced by the end of the year.

WATER.

Investigation of the State's underground water resources continued throughout the year, a total of £170,345 being spent on this work including £46,020 made available by the Commonwealth under the State Grants (Water Resources) Act.

The Department's Hydrological Division of the Geological Survey also continued to assist other Government Departments, Local Authorities and farmers to establish water supplies.

TABLE 1

Quantity and Value of Minerals, other than Gold and Silver, produced during Years 1964 and 1965
Western Australia

Description of Minerals	1964		1965		Increase or Decrease for Year Compared with 1964	
	Quantity	Value	Quantity	Value	Quantity	Value
	Tons	£A	Tons	£A	Tons	£A
Alumina (from Bauxite)	117,724.00	3,531,720	148,468.00	4,454,040	+ 30,744.00	+ 922,320
Asbestos (Chrysotile)	536.19	43,681	402.09	28,839	— 134.10	— 14,842
(Crocidolite)	10,614.14	1,062,100	9,279.94	873,040	— 1,334.20	— 189,060
Barytes	171.70	683	750.75	3,003	+ 579.05	+ 2,320
Beryl	79.84	9,037	13.08	1,445	— 66.76	— 7,592
Building Stone* (Granite—Facing Stone)	33.00	600	106.00	2,120	+ 73.00	+ 1,520
(Lepidolite)	8.35	73	....	....	— 8.35	— 73
(Prase)	9.50	138	....	....	— 9.50	— 138
(Quartz—Dead White)	115.00	865	245.00	2,055	+ 130.00	+ 1,190
(Sandstone)	72.00	216	221.00	663	+ 149.00	+ 447
(Slate)	50.00	300	185.00	758	+ 135.00	+ 458
(Spongolite)	771.00	3,622	529.00	2,393	— 242.00	— 1,229
Clays (Bentonite)	676.28	1,571	921.45	1,819	+ 245.17	+ 248
(Cement Clay)	27,350.00	27,990	25,989.00	29,280	— 1,361.00	+ 1,290
(Fireclay)	47,251.50	43,036	61,102.00	42,167	+ 13,850.50	— 869
(Fuller's Earth)....	114.00	456	63.00	267	— 51.00	— 189
(Kaolin)	61.35	137	190.50	483	+ 129.15	+ 346
(White Clay-Ball Clay)	570.00	2,258	1,440.00	5,706	+ 870.00	+ 3,448
(Brick, Pipe and Tile Clay)	28,715.00	33,627	135,396.00	95,721	+ 106,681.00	+ 62,094
Coal	987,419.70	2,339,467	993,740.80	2,204,986	+ 6,321.10	— 134,481
Copper (Metallic By-Product)‡	46.14	7,230	....	....	— 46.14	— 7,230
Copper Ore and Concentrates	4,324.93	268,648	2,051.50	127,460	— 2,273.43	— 141,188
Cupreous Ore and Concentrates (Fertiliser)	2,196.69	125,985	1,078.76	49,617	— 1,117.93	— 76,368
Felspar	1,386.00	9,763	1,384.00	9,744	— 2.00	— 19
Glass Sand	10,047.00	7,029	9,259.00	6,084	— 788.00	— 945
Gypsum	44,998.12	53,778	46,607.00	44,577	+ 1,608.88	— 9,201
Iron Ore (Pig Iron recovered)	47,906.00	1,101,608	40,673.00	935,479	— 7,233.00	— 166,129
(Ore Exported)	1,280,864.00	1,270,189	2,240,939.00	2,222,269	+ 960,075.00	+ 952,080
Lead Ores and Concentrates	3,354.17	92,632	4,877.93	196,319	+ 1,523.76	+ 103,687
Limestone*	31,639.00	42,650	565,830.00	313,686	+ 534,191.00	+ 271,036
Lithium Ores (Petalite)	208.00	1,591	310.00	2,371	+ 102.00	+ 780
(Spodumene)	51.54	1,055	....	....	— 51.54	— 1,055
Magnesite	1,574.24	10,020	199.00	1,588	— 1,375.16	— 8,432
Manganese (Metallurgical, Battery and Low Grades)	38,823.81	457,338	100,208.20	1,075,926	+ 61,384.39	+ 618,588
Mineral Beach Sands (Ilmenite)	330,832.70	1,538,175	392,891.22	1,926,188	+ 62,058.52	+ 388,013
(Monazite)	1,317.19	54,475	1,068.00	52,151	— 249.19	— 2,324
(Rutile)	825.51	25,771	225.00	7,994	— 600.51	— 17,777
(Leucoxene)	643.19	11,894	484.00	10,806	— 159.19	— 1,088
(Zircon)	20,068.72	195,637	27,879.67	375,134	+ 7,810.95	+ 179,497
Ochre (Red)	323.51	1,941	186.65	1,120	— 136.86	— 821
Phosphatic Guano	....	....	15.00	150	+ 15.00	+ 150
Pyrites Ore and Concentrates (For Sulphur)	58,396.00	368,782	59,179.94	384,122	+ 783.94	+ 15,340
Talc	5,431.69	75,002	7,087.79	102,705	+ 1,656.10	+ 27,703
Tanto/Columbite Ores and Concentrates	14.57	13,287	9.87	8,873	— 4.70	— 4,414
Tin	637.04	620,391	675.58	778,257	+ 38.54	+ 157,866
Tungsten Ores and Concentrate—Scheelite	4.31	1,174	....	....	— 4.31	— 1,174
Total	....	13,457,622	....	16,381,405	....	+ 2,923,783

TABLE 1 (a)

Quantity and Value of Gold and Silver Exported and Minted during Years 1964 and 1965

Description of Minerals	1964		1965		Increase or Decrease for Year Compared with 1964	
	Quantity	Value	Quantity	Value	Quantity	Value
	Fine Oz.	£A	Fine Oz.	£A	Fine Oz.	£A
Gold (Exported and Minted)....	712,847.00	† 11,149,943	659,436.98	† 10,361,082	— 53,410.02	— 788,861
Silver (Exported and Minted)	245,557.97	143,841	290,622.68	170,206	+ 45,064.71	+ 26,365
Total	....	11,293,784	....	10,531,288	....	— 762,496
Grand Total	....	24,751,406	....	26,912,693	....	+ 2,161,287

* Incomplete—figures relate only to production reported to the Department from holdings under the Mining Act.
† Including Overseas Gold Sales 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	
	1964	1965	1964	1965	1964*	1965*
	Fine oz.	Fine oz.	Per cent.	Per cent.	Dwts.	Dwts.
1. Kimberley	16	11	.002	.002	5.333	....
2. West Kimberley	....	....	....	....	....	....
3. Pilbara	968	508	.135	.077	13.615	11.043
4. West Pilbara	....	....	....	....	....	....
5. Ashburton	1	....	....	....	....	....
6. Gascoyne	311	260	.044	.040	40.129	53.061
7. Peak Hill	18	101	.003	.015	....	1.549
8. East Murchison	847	1,243	.119	.189	12.614	12.027
9. Murchison	71,414	55,477	9.981	8.452	7.514	6.596
10. Yalgoo	....	1	....	....	....	....
11. Mt. Margaret	909	256	.127	.039	7.169	4.221
12. North Coolgardie	17,858	13,880	2.496	2.115	10.246	9.479
13. Broad Arrow	3,027	3,056	.423	.426	3.926	3.909
14. North-East Coolgardie	173	335	.024	.051	11.344	39.463
15. East Coolgardie	509,984	477,900	71.279	72.811	4.620	4.506
16. Coolgardie	4,008	4,628	.560	.705	17.735	23.463
17. Yilgarn	2,784	2,238	.389	.341	11.485	16.235
18. Dundas	100,864	95,393	14.097	14.534	11.053	10.442
19. Phillips River	†2,210	†1,064	.309	.162	....	....
20. South-West Mineral Field	87	....	.012	....	25.217	....
21. State Generally	2	4	....	.001	....	....
	715,481	656,355	100.000	100.000	5.408	5.188

* 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 1965

State	Output of Gold	Value*†	Percentage of Total
	Fine oz.	£A.	%
Western Australia	659,437	10,303,703	74.697
Victoria	21,284	332,562	2.411
New South Wales	9,825	153,516	1.113
Queensland	77,615	1,212,734	8.792
Tasmania	30,084	470,063	3.408
South Australia	3	47	....
Northern Territory	84,571	1,321,422	9.579
Total	882,819	13,794,047	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 Mining Companies during 1965, *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	
		1965	Grand Total to end of 1965
		£A	£A
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.	150,000	7,815,626
	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	3,383,671
	Great Boulder G.M.s Ltd.	131,250	9,875,025
	Lake View & Star Ltd.	175,000	(b) 11,205,750
	North Kalgurli (1912) Ltd.	51,563	3,490,781
	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	7,052,500
	Various Companies	....	786,162
	Totals	1,181,047	73,789,283

(*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 in 1948 by Edna May (W.A.) Amalgamated, N.L.

TABLE 5

Total Coal output from Collie River Mineral Field, 1964 *and* 1965, *estimated Value therefrom, 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
	Tons	£A	No.	No.	No.	Tons	Tons	Tons
Deep Mining—								
1964	644,107	1,807,333	136	519	655	4,736	1,241	983
1965	508,260	1,480,308	110	467	577	4,621	1,088	881
Open Cut Mining—								
1964	343,313	532,134	110	....	110	3,121	....	3,121
1965	485,481	724,678	183	....	183	2,653	....	2,653
Totals—								
1964	987,420	2,339,467	246	519	765	4,014	1,903	1,291
1965	993,741	2,204,986	293	467	760	3,392	2,128	1,308

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 1965 *and in force as at* 31*st December,* 1965 (*Compared with* 1964)

—	Applied for 1964 No.	Applied for 1964 Acreage	Applied for 1965 No.	Applied for 1965 Acreage	In Force 1964 No.	In Force 1964 Acreage	In Force 1965 No.	In Force 1965 Acreage
Gold—								
Gold Mining Leases	79	1,433	73	1,356	953	17,716	960	18,032
Dredging Claims	....	....	3	315	2	312	2	19
Prospecting Areas	489	8,526	460	7,968	389	6,660	384	6,725
Temporary Reserves	346	117,097	228	68,700	342	115,390	475	141,198
Totals	914	127,056	764	78,339	1,686	140,078	1,821	165,974
Coal—								
Coal Mining Leases	8	2,319	21	5,463	66	19,529	49	14,467
Prospecting Areas	....	....	....	....	....	....	....	....
Temporary Reserves	....	....	11	1,863,040	3	3,020,800	14	4,883,840
Totals	8	2,319	32	1,868,503	69	3,040,329	63	4,898,307
Other Minerals—								
Mineral Leases	63	8,946	72	16,955	169	10,640	135	9,836
Dredging Claims	165	21,916	149	20,817	235	22,444	352	33,560
Mineral Claims	171	21,800	373	55,654	1,096	103,814	1,345	141,265
Prospecting Areas	85	1,854	172	3,892	80	1,759	124	2,728
Temporary Reserves	59	24,347,004	215	217,289,440	153	33,480,754	256	103,536,000
Totals	543	24,401,520	981	217,386,758	1,733	33,619,411	2,212	103,723,389
Other Holdings—								
Miner's Homestead Leases	9	954	11	2,656	346	33,552	343	31,702
Miscellaneous Leases	8	2,865	6	112	118	1,723	117	1,719
Residence Areas	2	1	1	1	71	23	71	23
Business Areas	....	....	....	....	27	22	27	16
Machinery Areas	4	18	....	....	28	77	25	67
Tailings Areas	2	8	....	....	25	99	25	97
Garden Areas	1	1	2	6	71	223	67	207
Quarrying Areas	3	72	2	29	10	146	13	180
Water Rights	7	30	22	543	134	2,499	143	2,630
Licenses to Treat Tailings	33	....	40	....	25	....	34	....
Totals	69	3,949	84	3,347	855	38,364	865	36,641
Grand Totals	1,534	24,534,844	1,861	219,336,947	4,343	36,838,182	4,961	108,824,311

TABLE 6 (a)

SPECIAL ACTS

Total Number and Acreage of Mining Leases applied for during 1965 *and in force as at* 31*st December,* 1965 (*Compared with* 1964)

Holding	Applied for 1964 No.	Applied for 1964 Acreage	Applied for 1965 No.	Applied for 1965 Acreage	In Force 1964 No.	In Force 1964 Acreage	In Force 1965 No.	In Force 1965 Acreage
Mineral Leases	1	10,240	232	201,461	2	1,817,111	2	1,816,960

TABLE 6 (b)

PETROLEUM ACT

Total Number and Acreage of Permits to Explore and Licenses to Prospect applied for during 1965 *and in force as at* 31*st December,* 1965 (*Compared with* 1964)

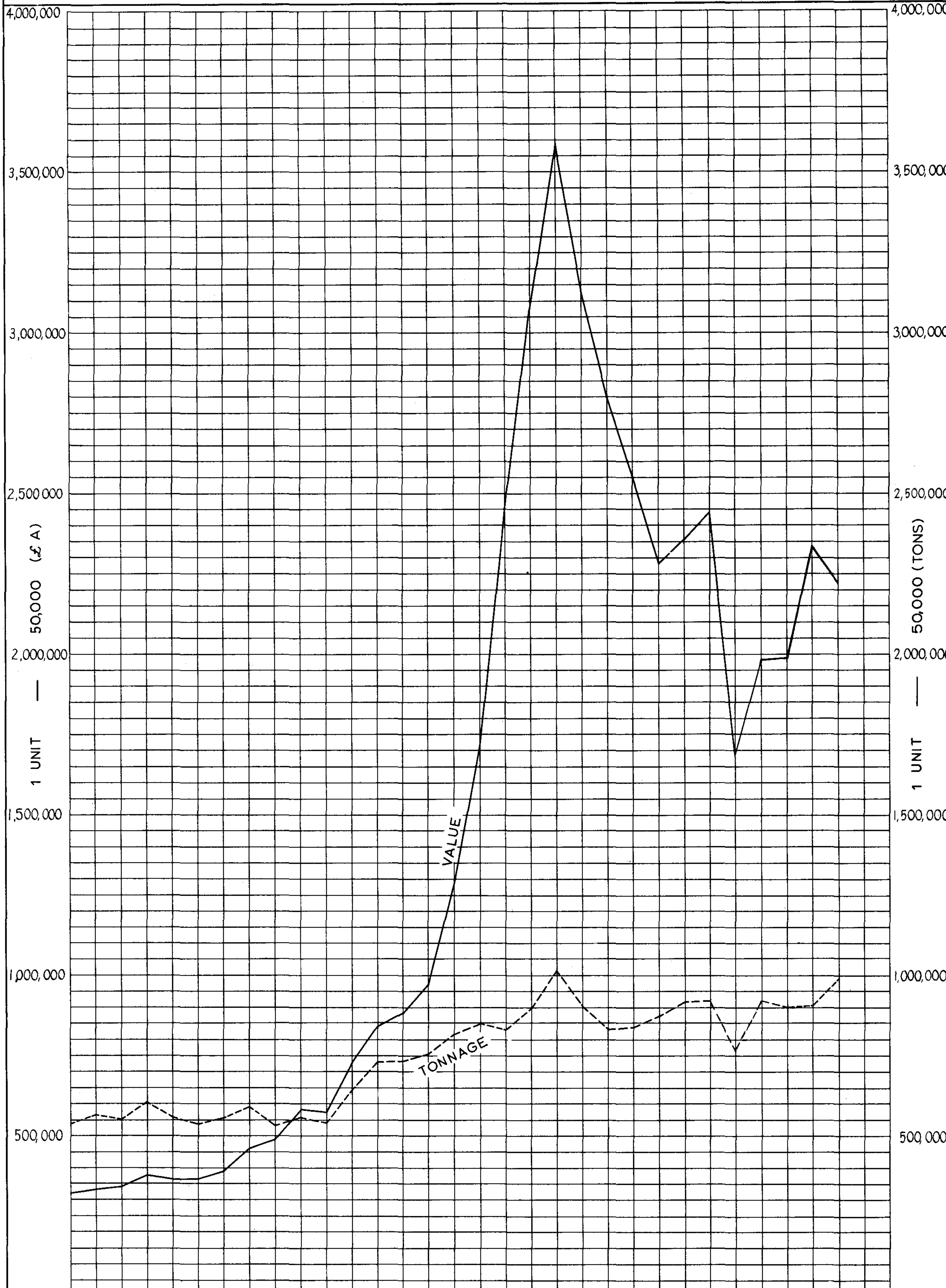
Holding	Applied for 1964 No.	Applied for 1964 Acreage	Applied for 1965 No.	Applied for 1965 Acreage	In Force 1964 No.	In Force 1964 Acreage	In Force 1965 No.	In Force 1965 Acreage
Permits to Explore	12	112,652,800	2	4,108,800	46	525,139,840	41	484,947,200
Licenses to Prospect	20	2,019,200	30	3,817,600	37	4,462,760	57	6,722,560
Totals	32	114,672,000	32	7,926,400	83	529,602,600	98	491,669,760

Total Area of Leases Applied for, Approved and in Force as at 31st December, 1965

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	....	....	....	....	....	136	....	....	....	....	....	5
Black Range	....	....	65	....	....	....	....	....	....	....	....	....
Broad Arrow	79	80	253	....	....	....	....	....	....	....	....	5
Bulong	12	12	48	....	....	....	....	....	....	....	....	3
Collie .... }	....	....	....	5,273	320	13,847	....	....	....	96	....	....
Private Property .... }	....	....	....	370	....	620	....	....	....	....	....	....
Coolgardie	130	24	684	198	6	61	119	19	859	....	....	60
Cue	....	....	60	....	....	....	....	....	1,233	....	....	....
Day Dawn	....	....	438	....	....	....	....	....	20	....	....	....
Dundas	798	798	6,919	....	....	....	....	....	909	....	....	....
East Coolgardie	55	169	5,370	....	....	....	20	....	3,353	....	....	1,180
Gascoyne	39	12	60	....	....	8	....	....	....	....	....	....
Greenbushes	....	....	....	153	20	6,631	....	....	588	....	....	....
Kanowna	12	12	22	....	....	....	....	....	702	....	....	....
Kimberley	....	....	34	....	....	....	....	....	....	....	....	....
Kunanalling	....	24	47	....	....	....	....	....	520	....	....	....
Kurnalpi	12	....	72	....	....	....	....	....	....	....	....	....
Lawlers	....	72	332	....	....	....	....	....	1,110	....	....	24
Marble Bar	92	12	311	48	....	40	12	....	23	8	8	66
Meekatharra	24	24	154	....	12	12	....	....	1,866	....	....	1
Menzies	34	34	364	....	....	....	....	....	740	....	....	10
Mount Magnet	....	....	856	....	....	38	....	....	30	....	....	....
Mount Malcolm	30	30	170	....	....	....	....	....	1,270	....	....	....
Mount Margaret	....	....	42	....	....	....	....	....	58	....	....	....
Mount Morgans	....	....	81	29	....	....	....	....	....	....	....	....
Niagara	....	....	53	....	....	....	....	....	20	....	....	....
Northampton .... }	....	....	....	25	25	107	....	....	53	....	....	....
Private Property .... }	....	....	....	....	....	33	....	....	....	....	....	....
Nullagine	....	....	222	....	....	....	....	....	22	....	....	48
Peak Hill	....	....	42	100	....	441	....	....	250	....	....	5
Phillips River .... }	....	....	21	2,417	....	246	500	....	14,166	....	....	....
Private Property .... }	....	....	....	12,300	....	....	....	....	....	....	....	....
South-West .... }	....	....	48	....	....	....	....	....	....	....	....	2
Private Property .... }	....	72	....	1,100	1,100	1,100	....	....	....	....	....	....
Ularring	....	....	120	....	....	....	....	....	120	....	....	....
West Kimberley	....	....	....	....	....	755	....	....	....	....	....	75
West Pilbara	6	6	62	....	100	132	1,500	....	11	....	....	141
Wiluna	....	....	24	....	24	....	....	....	3,426	....	....	11
Yalgoo	....	....	76	109	....	....	....	....	10	....	....	....
Yerilla	....	....	376	....	....	....	....	....	10	....	....	....
Yilgarn .... }	33	53	558	96	96	96	505	....	433	....	....	57
Private Property .... }	....	....	48	....	....	....	....	....	....	....	....	....
Outside Proclaimed	....	....	....	200	....	....	....	....	....	....	....	....
Totals	1,356	434	18,032	22,418	1,703	24,303	2,656	19	31,802	104	8	1,693

GRAPH OF COAL OUTPUT

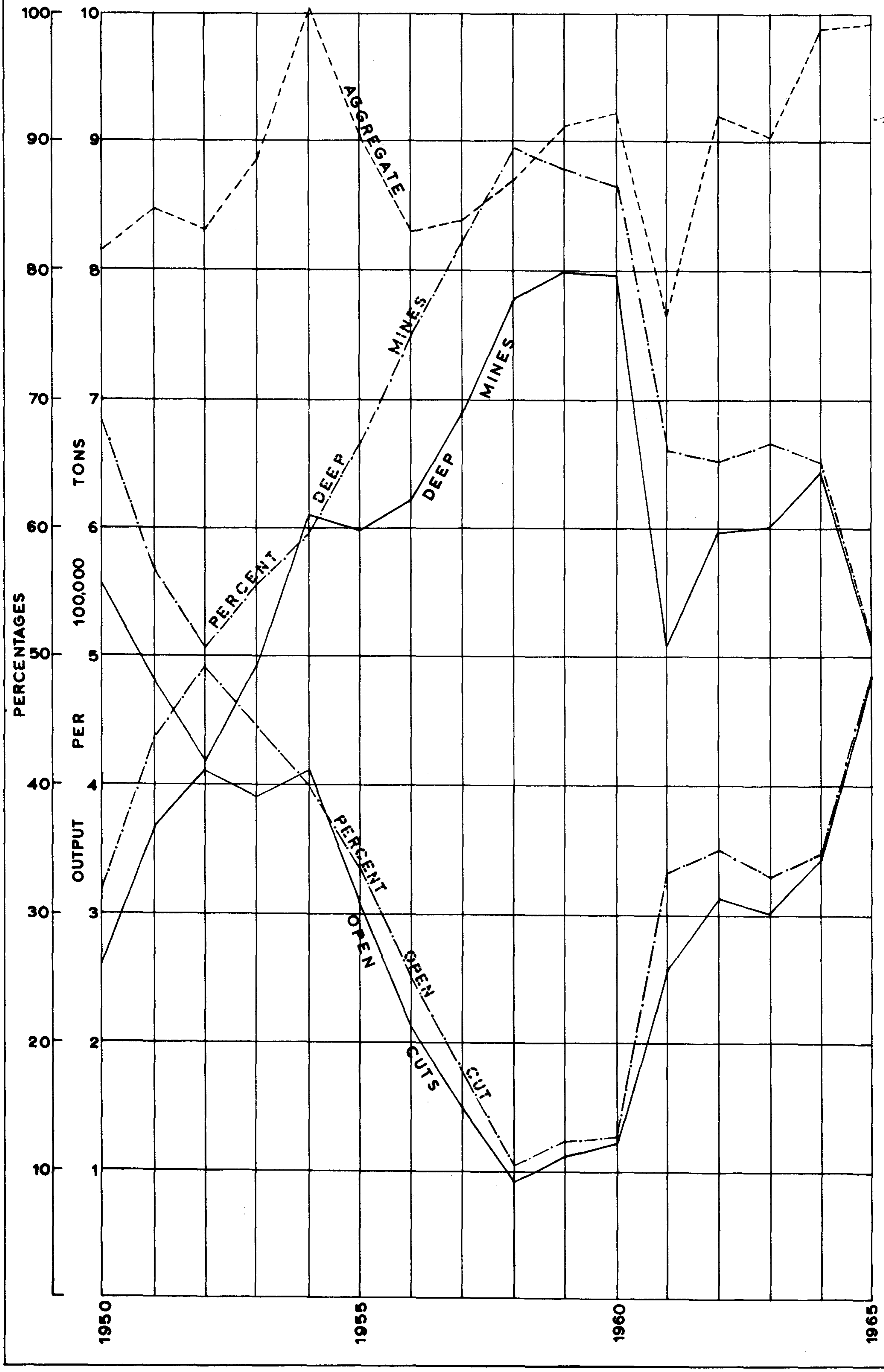
SHOWING QUANTITIES AND VALUES AS REPORTED TO MINES DEPT.



YEAR	VALUE £ A	TONS
1935	318,013	537188
1936	331,565	565075
1937	340,444	553510
1938	375,088	604793
1939	362,811	557535
1940	364,500	539427
1941	389,278	556574
1942	461,495	581176
1943	489,721	531546
1944	583,075	558322
1945	572,896	543363
1946	730,104	642287
1947	840,249	730506
1948	880,236	732938
1949	972,245	750594
1950	1287,749	814351
1951	1,716,788	848475
1952	2,457,236	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	2,280,149	870882
1959	2,356,532	917434
1960	2,439,195	922393
1961	1,630,259	765,740
1962	1,980,778	919,112
1963	1,985,060	902,495
1964	2,339,467	987,420
1965	2,204,986	993,741
1966		
1967		

GRAPH OF TREND IN COAL OUTPUT

SHOWING COMPARISON OF ANNUAL TONNAGE AND PERCENTAGES
BETWEEN DEEP AND OPEN CUT MINING



Total Area of Claims and Authorised Holdings Applied for, Granted and in Force as at 31st December, 1965

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	....	....	....	140	140	4,104	....	....	6	21
Black Range	48	48	48	....	....	24	....	....	1	11
Broad Arrow	910	843	684	197	125	....	....	....	10	11
Bulong	145	149	149	....	....	123	....	....	....	....
Collie .... }	....	....	....	....	....	....	....	....	....	5
Private Property .... }	....	....	....	....	....	....	....	....	....	....
Coolgardie	2,065	1,924	1,668	1,390	1,440	2,766	....	6	33	196
Cue	88	88	88	252	252	376	3	....	1	64
Day Dawn	63	63	63	....	....	....	....	....	20	....
Dundas	216	216	216	5,067	4,095	6,324	....	....	17	92
East Coolgardie	492	540	502	24	24	48	1	1	262	739
Gascoyne	....	....	....	2,986	3,022	3,800	....	....	....	56
Greenbushes	....	....	....	....	....	485	....	....	69	18
Kanowna	194	178	154	....	....	....	....	....	8	....
Kimberley	12	12	12	....	....	1,983	....	....	....	14
Kunanalling	255	219	219	....	....	....	....	....	25	....
Kurnalpi	156	132	96	....	....	....	....	....	....	....
Lawlers	314	314	290	24	24	66	....	....	12	....
Marble Bar	233	189	153	36,869	38,958	69,368	564	196	905	168
Meekatharra	283	266	290	414	414	600	....	....	5	105
Menzies	512	452	422	2,388	344	420	....	....	24	34
Mount Magnet	307	339	339	120	....	....	1	1	34	119
Mount Malcolm	402	378	258	....	....	....	4	1	195	85
Mount Margaret	130	130	106	24	24	24	....	....	4	....
Mount Morgans	60	60	60	120	96	125	....	....	1	....
Niagara	36	12	12	....	....	....	2	2	6	....
Northampton .... }	....	....	....	3,224	718	1,296	....	....	....	22
Private Property .... }	....	....	....	....	....	10	....	....	....	....
Nullagine	372	72	72	13,187	2,957	8,517	....	....	61	20
Peak Hill	....	....	....	381	192	1,191	....	....	8	....
Phillips River .... }	120	120	144	58	73	4,168	....	....	9	35
Private Property .... }	....	....	....	....	....	721	....	....	....	....
South-West .... }	53	14	14	1,521	1,247	19,747	....	....	7	887
Private Property .... }	40	....	....	5,182	830	17,396	....	....	....	....
Ularring	116	140	116	168	144	114	....	....	13	....
West Kimberley	....	....	....	....	....	48	5	5	51	6
West Pilbara	....	....	....	3,376	2,826	28,631	....	....	63	30
Wiluna	54	24	24	24	24	24	....	....	1,334	....
Yalgoo	32	32	32	2,629	181	960	....	....	22	12
Yerilla	36	12	12	....	....	....	....	....	12	1
Yilgarn .... }	539	495	501	142	37	3,474	....	....	25	....
Private Property .... }	....	....	....	360	....	....	....	....	....	....
Outside Proclaimed .... }	....	....	....	96	....	620	....	....	....	....
Private Property .... }	....	....	....	....	....	....	....	....	....	....
Totals	8,283	7,461	6,744	80,363	58,187	177,553	580	212	3,243	2,751

Claims and Authorised Holdings in Force as at 31st December, 1965

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	92	....	....	26	4,012	....	....	....	....	....	....	....	....	....	....	....	....	1	6
Black Range	3	48	....	....	1	24	4	1	....	....	....	....	....	....	....	....	....	....	....	....
Broad Arrow	42	684	....	....	....	....	1	1	1	1	....	....	....	....	....	....	3	8	....	....
Bulong	8	149	....	....	2	123	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Collie .... }	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Private Property .... }	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Coolgardie	97	1,793	....	....	19	2,641	3	1	....	....	1	1	1	3	3	8	6	20	....	....
Cue	14	240	....	....	10	224	4	1	....	....	....	....	....	....	....	....	....	....	....	....
Day Dawn	4	63	....	....	....	....	....	....	....	....	....	....	....	....	4	20	....	....	....	....
Dundas	24	492	....	....	60	6,048	....	....	....	....	....	....	1	5	....	....	2	12	....	....
East Coolgardie	37	526	....	....	1	24	31	8	....	....	2	4	12	56	4	17	13	39	7	114
Gascoyne	3	72	....	....	23	3,728	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Greenbushes	....	....	....	....	8	485	1	1	....	....	....	....	....	....	9	37	2	31	....	....
Kanowna	10	154	....	....	....	....	....	....	....	....	....	....	....	....	2	7	1	1	....	....
Kimberley	1	12	....	....	11	1,983	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Kunanalling	12	219	....	....	....	....	....	....	....	....	....	....	....	....	....	....	3	25	....	....
Kurnalpi	5	96	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Lawlers	14	314	....	....	3	42	....	....	....	....	2	6	1	5	....	....	1	1	....	....
Marble Bar	33	710	338	30,641	326	38,170	2	1	6	6	7	21	2	10	3	3	38	840	1	24
Meekatharra	21	404	....	....	3	486	....	....	....	....	....	....	....	....	....	....	2	5	....	....
Menzies	29	542	....	....	1	300	....	....	....	....	1	1	....	....	3	9	6	14	....	....
Mount Magnet	21	339	....	....	....	....	2	2	....	....	....	....	....	....	16	27	3	5	....	....
Mount Malcolm	13	258	....	....	....	....	....	....	....	....	....	....	....	....	7	29	11	166	....	....
Mount Margaret	6	130	....	....	....	....	....	....	....	....	....	....	....	....	....	....	4	4	....	....
Mount Morgans	7	156	....	....	1	29	....	....	....	....	....	....	....	....	....	....	1	1	....	....
Niagara	1	12	....	....	....	....	....	....	....	....	....	....	....	....	....	....	3	6	....	....
Northampton .... }	6	114	....	....	13	1,182	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Private Property .... }	....	....	....	....	1	10	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Nullagine	15	294	2	600	261	7,695	....	....	....	....	2	2	3	4	4	7	15	48	....	....
Peak Hill	7	168	....	....	29	1,023	1	1	....	....	2	8	....	....	....	....	....	....	....	....
Phillips River .... }	11	227	....	....	43	4,085	....	....	....	....	1	2	1	2	....	....	....	....	1	5
Private Property .... }	....	....	....	....	4	721	....	....	....	....	....	....	....	....	....	....	....	....	....	....
South-West .... }	3	62	9	1,817	156	17,882	....	....	....	....	....	....	....	....	....	....	2	7	....	....
Private Property .... }	2	48	5	521	120	16,827	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Ularring	12	230	....	....	....	....	....	....	....	....	1	1	2	4	....	....	7	8	....	....
West Kimberley	....	....	....	....	1	48	....	....	....	....	2	10	....	....	1	5	1	5	3	31
West Pilbara	7	152	....	....	177	28,479	4	1	12	6	....	....	....	....	4	19	8	37	....	....
Wiluna	2	48	....	....	....	....	....	....	....	....	1	1	1	3	1	5	5	1,325	....	....
Yalgoo	4	68	....	....	8	924	....	....	6	2	1	5	1	5	....	....	1	10	....	....
Yerilla	1	12	....	....	....	....	....	....	....	....	....	....	....	....	....	....	5	12	....	....
Yilgarn .... }	29	525	....	....	34	3,450	18	5	2	1	2	5	....	....	6	14	....	....	....	....
Private Property .... }	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Outside Proclaimed .... }	....	....	....	....	3	620	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Private Property .... }	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Totals	508	9,453	354	33,579	1,345	141,265	71	23	27	16	25	67	25	97	67	207	143	2,630	13	180

Number and Area of all Leases in Force as at 31st December, 1965

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	6	65	....	....	....	....	....	....
Broad Arrow	17	253	....	....	....	....	1	5
Bulong	3	48	....	....	....	....	1	3
Collie	....	....	47	13,847	....	....	....	....
Private Property	....	....	2	620	....	....	....	....
Coolgardie	38	684	9	61	20	859	6	60
Cue	4	60	....	....	6	1,233	....	....
Day Dawn	21	438	....	....	1	20	....	....
Dundas	313	6,919	....	....	19	909	....	....
East Coolgardie	302	5,370	....	....	67	3,353	67	1,180
Gascoyne	3	60	1	8	....	....	....	....
Greenbushes	....	....	39	6,631	11	588	....	....
Kanowna	2	22	....	....	12	702	....	....
Kimberley	2	34	....	....	....	....	....	....
Kunanalling	2	47	....	....	2	520	....	....
Kurnalpi	3	72	....	....	....	....	....	....
Lawlers	18	332	....	....	5	1,110	1	24
Marble Bar	28	311	2	40	3	23	9	92
Meekatharra	8	154	1	12	11	1,866	1	1
Menzies	22	364	....	....	7	740	1	10
Mount Magnet	54	856	4	38	2	30	....	....
Mount Malcolm	9	170	....	....	9	1,270	....	....
Mount Margaret	2	42	....	....	7	58	....	....
Mount Morgans	4	81	....	....	....	....	....	....
Niagara	3	53	....	....	1	20	....	....
Northampton	....	....	5	107	1	53	....	....
Private Property	....	....	2	33	....	....	....	....
Nullagine	12	222	....	....	2	22	2	48
Peak Hill	3	42	14	441	5	250	1	5
Phillips River	2	21	11	246	107	14,166	....	....
Private Property	....	....	....	....	....	....	....	....
South-West	2	48	....	....	....	....	....	....
Private Property	....	....	5	1,100	....	....	....	....
Ularring	9	120	....	....	1	20	....	....
West Kimberley	....	....	23	755	....	....	5	75
West Pilbara	4	62	10	132	2	11	7	141
Wiluna	1	24	....	....	16	3,426	3	11
Yalgoo	5	76	....	....	1	10	....	....
Yerilla	19	376	....	....	1	10	....	....
Yilgarn	36	558	2	96	24	433	10	57
Private Property	3	48	....	....	....	....	....	....
Outside Proclaimed	....	....	....	....	....	....	1	2
Totals	960	18,032	184	24,303	343	31,702	117	1,719

	Number	Acres
Gold Mining Leases on Crown Land	957	17,984
Gold Mining Leases on Private Property	3	48
Miner's Homestead Leases on Crown Land	343	31,702
Miner's Homestead Leases on Private Property		*Nil*
Mineral Leases on Crown Land	175	22,550
Mineral Leases on Private Property	9	1,753
Other Leases on Crown Land	117	1,719

MEN EMPLOYED

TABLE 7

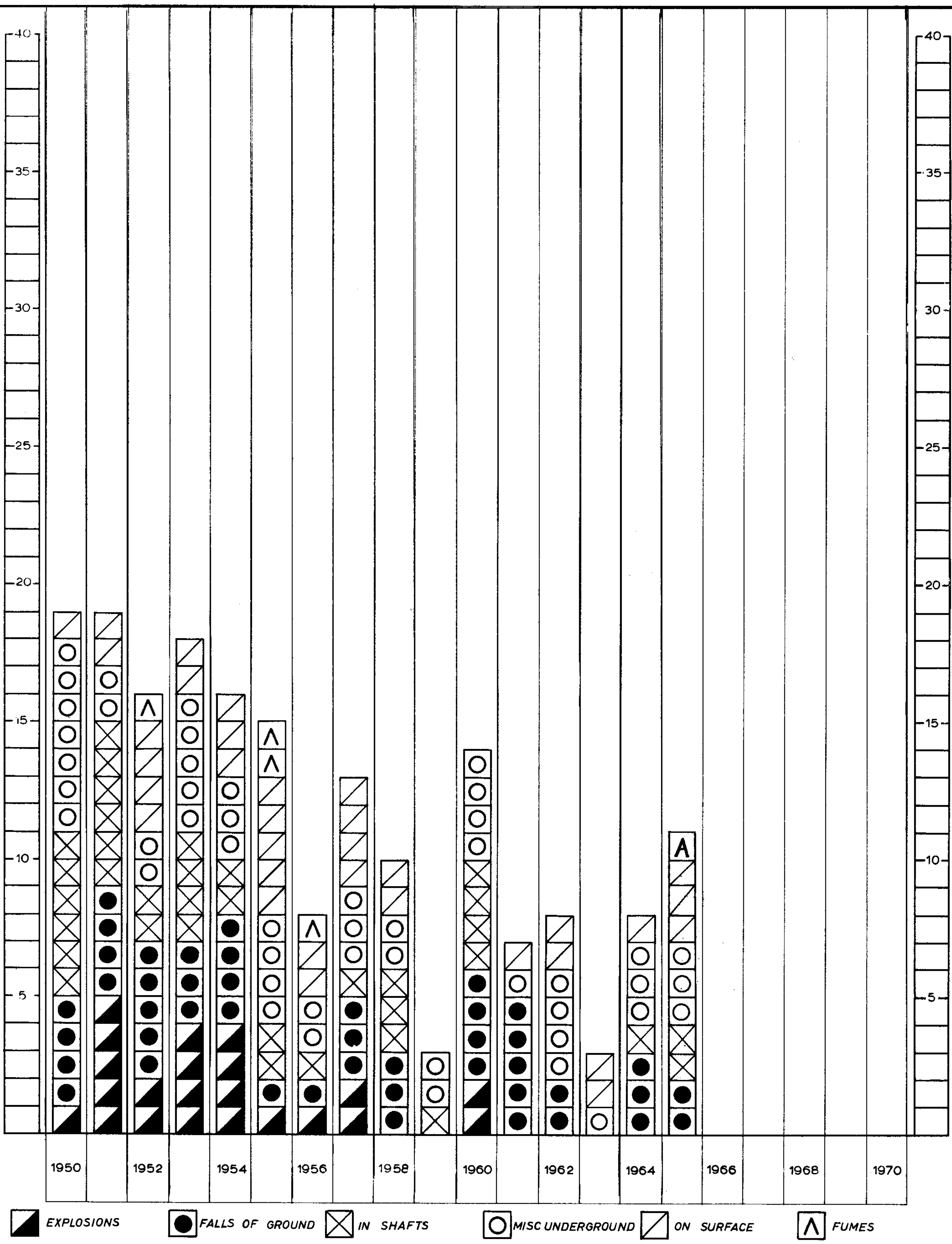
Average number of Men reported as engaged in Mining during 1964 *and* 1965

Goldfield	District	Total 1964	Total 1965
Kimberley	....	....	....
West Kimberley	....	....	....
Pilbara	Marble Bar	30	26
	Nullagine	18	14
West Pilbara	....	1	1
Ashburton	....	....	....
Gascoyne	....	1	2
Peak Hill	....	2	2
East Murchison	Lawlers	25	34
	Wiluna	5	4
	Black Range	4	6
Murchison	Cue	33	32
	Meekatharra	10	10
	Day Dawn	16	7
	Mt. Magnet	247	208
Yalgoo	....	....	1
Mt. Margaret	Mt. Morgans	3	12
	Mt. Malcolm	25	25
	Mt. Margaret	3	6
North Coolgardie	Menzies	101	102
	Ularring	31	18
	Niagara	5	4
	Yerilla	19	9
Broad Arrow	....	88	85
North-East Coolgardie	Kanowna	19	13
	Kurnalpi	13	8
East Coolgardie	East Coolgardie	3,047	2,883
	Bulong	10	9
Coolgardie	Coolgardie	107	108
	Kunanalling	19	19
Yilgarn	....	157	136
Dundas	....	344	310
Phillips River	....	....	....
South-West Mineral Field	....	....	....
Total, Gold Mining	....	4,383	4,094

Minerals Other than Gold—	Total 1964	Total 1965
Alumina (from Bauxite)	273	317
Asbestos	370	366
Barytes	1	1
Beryl	12	6
Building Stone	7	9
Clays	16	20
Coal	765	760
Copper	73	64
Cupreous Ore (Fertiliser)	54	43
Felspar	6	6
Glass Sand	3	3
Gypsum	16	14
Iron Ore	448	357
Lead	21	33
Limestone	18	19
Manganese	74	68
Mineral Beach Sands (Ilmenite, etc.)	262	311
Pyrites	99	94
Talc	4	5
Tanto/Columbite	9	9
Tin	104	147
Total, Other Minerals	2,635	2,652

DIAGRAM OF ACCIDENTS

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



PART 3—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 1965, gold, tin, tungsten, lead, copper and tantalite ores to the value of £19,134,502 have been treated at the State Batteries. Included in the above amount is gold premium of £7,392,473 and premium paid by sales of gold by the Gold Producers Association Ltd., of £44,748. £18,550,363 came from 3,502,835¾ tons of gold ore, £98,538 from 82,351¼ tons of tin ore, £18,850 from 3,960 tons tungsten ore, £447,835 from 38,852½ tons lead ore, £5,966 from 220½ tons of copper ore and £12,950 from 203¼ tons of tantalite ore.

During the year 41,481 tons of gold ores were crushed for 14,937 ozs. bullion, estimated to contain 12,660 ozs fine gold, equal to 6 dwts 3 grs per ton. The average value of sands after amalgamation was 2 dwts 3 grs per ton, making the average head value 8 dwts 6 grs per ton. Cyanide plants produced 2,467 ozs. fine gold, giving a total estimated production for the year of 15,127 ozs. fine gold valued at £237,672.

The working expenditure for the year for all plants was £231,889 and the revenue was £42,515 giving a working loss of £189,374 which does not include depreciation or interest. Since the inception of State Batteries, the Capital expenditure has been £848,665 made up of £669,053 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 £28,342 compared with £28,662 for 1964.

The working expenditure from inception to the end of 1964 exceeds revenue by £2,252,210.

(b) Prospecting Scheme.

The number of men approved for assistance under the above Scheme during 1965 was 23 as compared with 46 during the previous year. There were 30 cancellations of assistance in the twelve months and allowing for 2 men under suspension on 31/12/65 there were 32 men in receipt of assistance at that date.

The total cost of maintaining the Scheme for the year was £9,255 and refunds amounted to £1,800.

During the year crushings reported from assisted prospectors totalled 2,008 tons for a return of 474 ozs of gold.

Progressive total figures since inception of the Scheme are as follows:—

Expenditure	£459,442
Refunds	£90,649
Ore Crushed	120,861 tons
Gold	55,829 ozs

The above expenditure figure includes £80,346 subsidised by the Commonwealth Government.

(c) Geological Survey of Western Australia

The Geological Survey continued to assist mining, agriculture and industry through the work of its various Divisions.

The comprehensive survey of blue asbestos deposits in the Hamersley Range area continued during 1965 and is expected to be completed in 1966.

Systematic regional geological mapping was again carried out in various areas from the Kimberleys down to the Yilgarn and Kalgoorlie fields and information given to mining companies and prospectors regarding regional geology and mineralisation.

In addition a new geological map of the State has been compiled and made available to the public.

Mapping of the Perth Sedimentary Basin continued and mapping of the Eucla Basin commenced during the year, and the writing of a Bulletin on the Devonian reef complexes was completed.

Engineering geology services were again provided to assist important developmental projects such as the Standard Gauge Railway, dam sites in the Darling Scarf South of Perth, the Gascoyne and the Kimberleys.

Underground water investigations were continued over wide areas of the State to find town water supplies for many centres, as well as towards assessment of the State's groundwater resources and the Hydrological Advisory Service was again provided for landholders, companies and Government departments.

PART 4—SCHOOL OF MINES.

(a) *Kalgoorlie*

For the first time in many years enrolments dropped below 300, and only 275 students were enrolled in 1965 as compared with 329 in 1964.

The decrease is unfortunate at a time when mining in W.A. urgently needs trained men, and although the lesser numbers may be partly attributed to the decreasing population in the Eastern Goldfields they also reflect the attraction of other careers in areas not so isolated as most mining centres.

Qualified staff again proved hard to get and despite advertisement throughout Australia and in Great Britain for lecturers to fill vacancies at the school only one position was filled.

Two students holding Chamber of Mines Scholarships completed Associateship Courses and all but one of the other ten scholarship students as well as two Mines Department scholarship students completed the year's work satisfactorily.

During the year 15 Associateship Diplomas and 21 Certificates were granted. In addition four students completed Technician Courses.

In addition to its teaching activities the school again provided its usual services to the industry and to the public. The Metallurgical Laboratory completed two investigations and also issued 274 certificates of testing and analysis. Free assays and/or determinations were made of 442 samples received at the school from prospectors.

Following a report by the committee on the future of tertiary education in Australia the Commonwealth Government indicated that it would assist colleges providing approved tertiary education and a grant of £61,500 has been made by it towards the cost of new mining and engineering buildings at the school.

As a result of this grant a contract was let for the work with the State Government contributing approximately £120,000 of the total cost of just over £180,000.

Further grants are being sought towards the overall plan for additional buildings and modernising existing ones.

(b) *Norseman*

Enrolments at the Norseman School again decreased by nine to 50 in 1965 as compared with 59 in 1964.

Two students who were awarded Reg Dowson Scholarships in 1964 completed the year's work satisfactorily and a further two scholarships were awarded in 1965.

Mr. W. L. Dutton who had been a member of the School Advisory Committee since 1942, resigned early in 1965 when he relinquished his position as General Superintendent of Central Norseman Gold Corporation. He rendered valuable service to the school during his long term with the committee.

His successor is Mr. R. Sainsbury who was appointed to the committee in place of Mr. Dutton, and later elected chairman.

PART 5—INSPECTION OF MACHINERY.

The number of useful boilers registered with the Inspection of Machinery Branch again increased substantially and at the end of the year 9,222 were registered as compared with 8,735 at the end of 1964.

During the year 5,540 thorough and 1,199 working inspections were made from which 5,555 certificates were issued. The corresponding figures for the previous year were 5,138, 908 and 5,159 respectively.

Seventy-seven boilers were condemned permanently, one temporarily, and 624 notices to repair were issued.

The total number of machinery groups registered at the end of the year was 52,479, an increase of 2,109 groups compared with the 50,370 registered at the end of 1964. Included in these figures are 681 lifts as against 601 in 1964, an increase of 80 installations.

Inspections made totalled 30,441 and 5,940 certificates were issued.

The total miles travelled in 1965 were 139,319 against 123,471 for the previous year—an increase of 15,848 miles. The average miles travelled per inspection increased from 3.23 in 1964 to 3.75 during 1965.

There was again an increase in the number of applications received for Engine Drivers, Crane Drivers and Boiler Attendants' Certificates. These totalled 658 in 1965 as compared with 530 during the previous year.

The Board of Examiners dealing with these applications granted 114 Engine Drivers, 336 Crane Drivers, 68 Boiler Attendants, 3 Interim Certificates and 11 copies—a total of 532 compared with 484 in 1964.

Total revenue from all sources was £16,827 compared with £17,052 in 1964—a decrease of £225.

Total expenditure was £53,358—an increase of £1,690 over that for 1964.

PART 6—GOVERNMENT CHEMICAL LABORATORIES.

The Laboratories continued to maintain close association with other Government Departments and with kindred associations during the year and staff officers now serve on 15 Committees—three more than in 1964.

Two major items of equipment obtained during the year for Laboratories, were a Unicam SP800A double beam ultraviolet and recording spectrophotometer and a high tension electrostatic separator.

The former is used mostly in the Food and Drugs Division for characterising chemical compounds—particularly complex organic chemicals, while the latter item is in the Engineering Chemistry Division for separating ores from their gangue material.

Although registrations only increased by 2% to 3,616 as compared with 3,551 in 1964, the number of samples received was 14,816—14% higher than 12,962 received the year before.

The samples came from 26 State Government Departments, Boards and Authorities, 6 Commonwealth Government Departments, the United States Navy and the general public. In the last category were a considerable number of samples from prospectors for free mineral identification or assay.

Agriculture and Water Supply Division.

There was a 10% decrease in the number of samples received by this Division in 1965 as compared with 1964, increased animal nutrition, cereal and fertiliser samples being more than offset by less pasture, fodder, soil and water samples.

Of 6,211 samples received 1,702 were of water, 1,470 pasture and fodder, 1,253 cereal, 503 soil, 317 fruit and vegetable, 205 fertiliser, 154 animal and 607 miscellaneous samples which included 353 of linseed.

As in previous years the bulk of the samples came from the Agriculture Department.

Engineering Chemistry Division.

Most of the work of this Division during the year was done for outside interests as sponsored projects, two of them being continued from the previous year.

These were productions of lightweight aggregate for concrete from local shale, and utilisation of titaniferous magnetite deposits containing vanadium.

A new research project—the effect of the method of heating beach sand on its electro-static separation—was commenced during the year, various investigations requested by local industry were carried out and technological advice and assistance was given to numerous Government and private interests.

Food, Drugs, Toxicology and Industrial Hygiene Division.

The works of this Division continued to come mainly from the Agriculture, Police, Public Health and Public Works Departments, the Milk Board and the Swan River Conservation Board and a total of 3,611 samples were received—100 more than in 1964.

The samples received included: Milk—588, Other Food—132, Industrial Hygiene—258, Human Toxicology—711, Sobriety—180, Traffic death—278, Pesticide—337, Linseed—211, Pollution—238, and the normal variety of miscellaneous work was carried out for other Government Departments and the general public.

Fuel Technology Division.

Investigations and samples allocated to this Division during the year totalled 137 as against 206 registrations in 1964.

The 1965 registrations ranged from a $3.00 sub-sieve size analysis of chocolate powder to a two-year $10,000 per annum grant by the National Coal Research Advisory Committee for an investigation of the reaction of solid carbon with metallic oxides in connection with the direct reduction of ores with coal.

Other projects concerned atmospheric pollution, building materials, fuels of various kinds and the drying of ilmenite beach sands.

Industrial Chemistry Division.

Of 82 samples and investigations allocated to this Division during the year, 63 were building materials including paints and plastics used in building and these were also the most numerous subjects of enquiries dealt with by the Division's Advisory Service.

As in previous years investigational and research work was carried out for other Government Departments and for industry, local firms and the public.

Mineralogy, Mineral Technology and Geo-Chemistry Division.

The number of samples examined during the year by this Division was double that of the previous year—4,838 as compared with 2,395.

The main cause of the increase was 2,077 arsenic samples which were received in connection with research into the nature and structure of Kalgoorlie ore bodies.

Other minerals of increased interest were clays (including bentonite), bauxite, copper, ilmenite, iron, lead and tin, while there was a corresponding decrease in the samples received for beryl, gold and silver, gypsum and manganese.

During the year 144 specimens were added to the Mineral Division Collection which now contains 3,736 specimens.

Physics and Pyrometry Section.

The work of this Section is divided into three headings—Pyrometry, Thermal Methods and X-ray Methods.

The only Pyrometry work received was for calibration of one optical pyrometer and seven mercury thermometers.

Regular use was made of the differential thermal apparatus during the year for confirming mineral diagnoses difficult to interpret by other means alone, while increasing use was made of the X-ray powder diffraction method as a means of rapid routine mineral identification.

PART 7—EXPLOSIVES BRANCH.

Inspection and control of explosives and of their transportation and storage was continued by the Explosives Branch of the Department throughout 1965.

Despite increasing importations and use of various new types of explosives the Branch maintained the high safety standards so necessary in connection with these dangerous materials, and there were very few accidents reported during the year.

Further progress was made with the draft Flammable Liquids Regulations which are being formulated under the Explosives and Dangerous Goods Act, 1961 to safeguard the storage and handling of petrol and similar liquids. Discussions with members of the Petroleum Marketing Engineers' Advisory Committee and other interested bodies classified and resolved many issues involved in the proposed Regulations and an amended draft was circulated late in 1965 for further comment and suggestion.

PART 8—MINE WORKERS RELIEF ACT AND MINERS PHTHISIS ACT.

Examination of mine workers continued during the year at the State X-ray Laboratory, Kalgoorlie and through the mobile X-ray unit which visited ten goldfields, the South West Mineral Field and Koolan and Cockatoo Islands.

In all 6,790 examinations were made as compared with 5,934 in 1964, an increase of 756.

Compensation payments under the Old Miners Phthisis Act totalled £7,838 as compared with £8,833 during the previous year and there were only 59 beneficiancies under that Act at the end of 1965 as against 77 on 31/12/64.

PART 9—CHIEF DRAFTSMAN'S BRANCH.

The increased mining and prospecting activity throughout the State was also reflected in additional work in this Branch during the year.

Survey of mining tenements was accelerated to cope with increasing numbers and the value of contract surveys carried out in 1965 was almost double that of 1964—£11,416 as compared with £5,799.

Technical plans prepared and drawn for the Geological Survey increased from 203 in 1964 to 315 in 1965 and 1,966 applications for all types of tenements were plotted on the departments public plans as compared with 1,558 during the previous year.

STAFF.

A major Departmental change occurred with the retirement of Mr. A. H. Telfer after 49 years' service in the department including 28 years as Under Secretary.

I am happy to say that he did not sever his connection with the Department entirely, but was appointed chairman of the Mining Advisory Committee with Messrs. G. Jennings and R. Ince as members.

I would like to take this opportunity of thanking Mr. Telfer personally for his help and guidance over the years and for his assistance since my appointment as Permanent Head.

I would also like to thank the members of his Committee for their assistance to the Department.

The year has again brought many problems and additional work, but all members of the staff have responded with loyalty and efficiency and I am glad to record my appreciation of their efforts.

In this summary of the various activities of the Department I have commented only on the principal items. Detailed reports of the responsible Branch officers are contained in Division II to X of the complete report.

I. R. BERRY,
Under Secretary for Mines.

Department of Mines, Perth.

DIVISION II

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Report of the State Mining Engineer for the Year 1965

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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 Assistant State Mining Engineer.

This year covers a period of remarkable expansion in several fields.

Iron mining is emerging from the exploration and development phase and entering the production phase.

The development of the beach mining industry is only a little less spectacular. All plants are working to capacity and expanding.

The Bauxite-Alumina industry is now firmly established.

Tin dredging at Greenbushes is in full operation and there has been considerable expansion in the Pilbara. Good rains have replenished the water supplies and there should be a record production in 1966.

Exploration for copper is very active and Ravensthorpe copper is doing better than for several years past.

The discovery of nickel at Kambalda near Kalgoorlie has not only created considerable interest in this particular deposit but has initiated a vigorous exploration campaign.

Some development of the pyrite industry must be expected to result from a current world sulphur shortage.

The asbestos industry is languishing to some extent mainly on account of labour shortage.

Gold mining has received some adverse publicity. It is true that there has been some reduction of ore mined and of gold produced but the mines are still very active and shaft sinking is in progress on several mines.

Good supplies of underground coal have been developed and the supplies of open cut coal are adequate for a long period.

The production of oil from Barrow Island should be an established fact in the coming year.

The drilling section has again proved to be of great value. One of the more interesting projects has been the exploration of Cockburn Sound by drilling from a mobile platform and from barges.

There must be a very considerable increase in production in 1966 and the wide spread exploration must surely produce some new deposits.

E. E. BRISBANE,
12th August, 1966. State Mining Engineer.

State Mining Engineer:

Mining activities for the year 1965 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

Mr. C. K. Sweeney, Senior Inspector of Mines, stationed at Collie retired on the 10th December. This position was filled by the appointment of Mr. R. S. Ferguson who commenced duties on the 16th November.

Our Leonora Office was closed following the retirement of Workmen's Inspector T. A. Birch who completed his term of appointment on the 22nd November.

ACCIDENTS

Fatal and serious mining accidents reported to the Department are shown below. The corresponding figures for 1964 are shown in brackets.

There were 11 (8) fatal and 410 (432) serious accidents.

In gold mines there were 6 (6) fatal and 257 (290) serious accidents. The number of men employed in such mines was 4,468 (4,785). The accident rate per 1,000 men was thus 1.34 (1.25) for fatal accidents and 57.52 (60.60) for serious accidents.

Fatal accidents in other mines included copper 1, manganese 1, iron ore 1, iron works 1, and limestone quarry 1.

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

TABLE A

Serious Accidents for 1965

Class of Accident	West Kimberley	Pilbara	West Pilbara	Ashburton	Murchison	Northampton	Mount Margaret	North Coolgardie	East Coolgardie	Dundas	Phillips River	Greenbushes	South-West	Collie	Total
Major Injuries — Exclusive of Fatal—															
Fractures—															
Head	1	....	....	....	....	....	....	....	....	....	....	....	....	....	1
Shoulder	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Arm	....	....	1	....	....	....	1	1	4	....	....	....	....	1	8
Hand	....	....	....	....	1	....	....	....	1	1	....	....	....	....	3
Spine	....	....	....	....	....	....	....	....	1	1	....	....	....	....	2
Rib	....	....	....	....	....	....	....	1	5	1	1	....	2	....	10
Pelvis	....	....	1	....	....	....	....	....	1	....	....	....	1	1	4
Thigh	....	....	....	1	....	....	....	....	1	....	....	....	....	....	2
Leg	....	....	....	....	....	....	....	....	2	....	....	....	....	....	2
Ankle	....	....	....	....	....	....	....	....	1	1	....	....	....	1	3
Foot	....	1	....	....	....	....	....	....	4	2	....	....	1	....	8
Amputations—															
Arm	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Hand	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Finger	....	....	....	....	1	....	....	....	1	....	....	....	....	2	4
Leg	....	....	....	....	....	....	....	....	1	....	....	....	....	....	1
Foot	....	....	....	....	....	....	....	....	1	....	....	....	....	....	1
Toe	....	....	....	1	....	....	1	....	....	....	....	....	1	....	3
Loss of Eye	....	....	....	....	....	....	....	....	....	1	....	....	....	....	1
Serious Internal	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Hernia	1	....	....	....	1	....	....	1	5	....	2	....	1	1	12
Dislocations	....	1	....	....	....	....	....	....	1	....	....	....	....	....	2
Other Major	1	....	....	....	....	....	....	....	....	....	....	....	....	....	1
Total Major	3	2	2	2	3	....	2	3	29	7	3	....	6	6	68
Minor Injuries—															
Fractures—															
Finger	3	....	....	....	....	....	....	....	10	1	....	....	1	....	15
Toe	....	....	....	....	1	....	....	....	2	1	....	....	....	1	5
Head	....	....	....	....	1	....	....	....	1	1	1	....	....	....	4
Eyes	....	1	....	....	....	....	....	1	10	1	....	....	....	....	13
Shoulder	....	....	....	....	....	....	....	....	3	....	....	....	1	....	4
Arm	....	....	1	2	....	....	....	....	12	1	....	....	3	....	19
Hand	....	3	2	4	1	....	....	....	45	5	4	....	7	6	77
Back	....	3	3	1	....	1	....	2	34	3	1	....	3	17	68
Rib	....	....	....	....	....	....	....	....	5	....	....	....	....	1	6
Leg	1	....	1	2	2	1	....	2	31	2	2	1	4	9	58
Foot	1	....	3	1	2	....	....	....	13	5	....	....	9	5	39
Other Minor	1	....	2	....	....	....	....	1	18	3	2	....	5	2	34
Total Minor	6	7	12	10	7	2	....	6	184	23	10	1	33	41	342
Grand Total	9	9	14	12	10	2	2	9	213	30	13	1	39	47	410

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.

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

TABLE B

Accidents segregated according to mineral mined

Mineral	Men Employed	Accidents		
		Fatal	Serious	Minor
Asbestos	366	....	14	58
Bauxite	317	....	5	34
Coal	760	....	47	236
Copper	107	1	13	35
Gold	4,468	6	257	1,155
Gypsum	14	....	....	....
Ilmenite	311	....	8	52
Iron Ore	357	2	12	37
Lead	33	....	2	....
Manganese	68	1	....	2
Oil Exploration	351	....	38	83
Pyrite	94	....	7	30
Tin	147	....	4	15
Other Minerals	50	....	....	....
Rock Quarries	254	1	3	11
Totals	7,697	11	410	1,748

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	....	....	....	....	....	....	....	....	....	....	....	....	....	....
West Kimberley	....	....	....	....	....	....	....	....	....	....	1	9	1	9
Pilbara	....	....	....	....	....	....	....	....	....	....	1	9	1	9
West Pilbara	....	....	....	1	....	....	....	....	....	8	....	5	....	14
Ashburton	....	....	....	....	....	....	....	....	....	....	....	12	....	12
Peak Hill	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Gascoyne	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Murchison	....	....	....	2	....	....	....	....	1	6	....	2	1	10
East Murchison	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Yalgoo	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Northampton	....	....	....	2	....	....	....	....	....	....	....	....	....	2
Mount Margaret	....	....	....	....	....	....	....	....	....	....	....	2	....	2
North Coolgardie	....	....	1	....	....	....	....	....	....	8	....	1	1	9
Broad Arrow	....	....	....	....	....	....	....	....	....	....	....	....	....	....
North-East Coolgardie	....	....	....	....	....	....	....	....	....	....	....	....	....	....
East Coolgardie	....	....	1	15	1	5	....	....	2	159	....	34	4	213
Coolgardie	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Yilgarn	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Dundas	....	2	....	2	....	1	....	....	....	16	....	9	....	30
Phillips River	....	....	....	....	1	....	....	....	....	8	....	5	1	13
Greenbushes	....	....	....	....	....	....	....	....	....	....	....	1	....	1
South-West	....	....	....	....	....	....	1	....	....	1	1	38	2	39
Collie	....	....	....	1	....	....	....	....	....	40	....	6	....	47
Total for 1965	....	2	2	23	2	6	1	....	3	246	3	133	11	410
Total for 1964	....	8	3	25	1	8	....	1	3	273	1	117	8	432

FATAL ACCIDENTS

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

Name and Occupation	Date	Mine	Details and Remarks
Durkin, Hugh (Underground Locomotive Driver)	5/1/65	Main Shaft, Great Boulder Gold Mines Ltd., Fimiston	During trucking operations on the 2,800 ft. level he was crushed between the locomotive he was driving and a side chute launder.
Rutley, Robert George (Plumber's Assistant)	6/1/65	Charcoal Iron and Steel Industry, Wundowie	Death was due to carbon monoxide poisoning resulting from the inhalation of gas from the No. 1 furnace.
Pisano, Carmelo (Underground Locomotive Driver)	24/4/65	Edwards Shaft, Great Boulder Gold Mines Ltd., Fimiston	Death due to a fractured skull received whilst driving a battery powered locomotive on the 1,400 ft. level. It is thought that he struck his head on a bearer.
Lutkevics, Oswald Josef (Rock Drill Operator)	30/4/65	M.C. 54L, Woody Woody, D. F. D. Rhodes Pty. Ltd.	Suffered head and internal injuries when the boom of a drilling machine fell on him. At the time of the accident he was endeavouring to alter the position of the boom without first inserting the safety bar.
Gouge, Ronald Joseph (Shaft Timberman)	19/5/65	Hamilton Shaft, Great Boulder Gold Mines Ltd., Fimiston	Received head injuries when he was jammed between shaft bearers and the counterweight in the No. 1 winze internal shaft.
McCallum, Mungo (Timberman)	28/6/65	Horseshoe No. 2 Shaft, Lake View and Star Ltd., Fimiston	Struck by a slab of rock which fell from the hanging wall of the 1,900 ft. level 15 lode cut and fill stope.
Picen, Lorenzo (Timberman)	15/7/65	Timoni Mine, Moonlight Wiluna G.M. Ltd., Mt. Ida	Death due to multiple chest injuries received when a slab of rock fell from the 400 ft. level hanging wall during retimbering operations.
Lulich, Nicholas (Truck Driver)	16/8/65	Bell Bros. Pty. Ltd., Tyler's Quarry, Spearwood	Lulich was sitting in his vehicle when an overloaded hoisting rope broke allowing the excavator bucket, loaded with limestone, to fall through the roof of the truck cab.
Rudan, Mate (Machine Miner)	6/9/65	Hill 50 G.M. N.L., Mt. Magnet	Rudan was working in a rise above the No. 12 level when the stage collapsed and he fell 85 ft. to his death. The stage collapsed when one of the pins supporting it broke. The pin was part of an old drill steel.
Pantelejevs, Jevgeni (Skipman)	20/10/65	Elverdton Shaft, Ravensthorpe Copper Mines N.L., Ravensthorpe	The rope detaching hook of the skip in which the deceased was riding broke when timber in the ascending skip fouled shaft timbers. The grippers failed to stop the skip which, with its load, fell about 600 ft. to the bottom of the shaft.
Boyd, Robert Lawrence (Truck Driver)	23/11/65	Cockatoo Island Dampier Mining Co. Ltd., Yampi	Boyd was the driver of a Euclid truck which was reversed over a high bank during mullock dumping operations.

WINDING MACHINERY ACCIDENTS.

Eleven accidents involving winding machinery were reported during the year and are briefly as follows.

Fatal.—(1) This accident in the Elverdton shaft appears under Fatal Accidents in this report.

Overwinds.—(2) An overwind occurred at the No. 8 level North Winze winder, Hill 50 G.M. N.L. on the 22nd January. The skipman was being raised to No. 8 level when the driver allowed his attention to wander and the "monkey" went through the limit switch which stopped the winder. No one was injured and no damage resulted.

On the 3rd May a cage was overwound at the Horseshoe No. 2 shaft, Lake View and Star Ltd. The rope was detached and the cage held by the grippers. The lugs of the detaching hook were open and 1½ inches above the thimble. No damage resulted but the detaching hook and connecting link were changed, and the rope cut.

Cages Hung Up.—(2) When normal testing operations of skip and cage safety appliances were being conducted in the Lake View shaft on the 25th January the north skip was hung up, by the grippers, below the 2,400 feet level. This resulted in an over run of 40 feet of rope which was cut and reshod.

On the 1st December an underground locomotive was accidentally knocked so that it protruded into the South Paringa shaft at No. 4 level plat. A descending skip struck the locomotive cab. The winder driver, noticing the change in motor noise and slack rope, stopped the winder. Two plat legs were damaged.

Derailments.—(2) A skip derailment occurred in the Royal shaft, Central Norseman Gold Corporation on the 21st January. Spillage caused the derailment as the skip was pulled away after being filled at the 700 bin. One centre leg was pulled out.

A skip derailment apparently caused by spillage occurred at the Regent shaft, Central Norseman Gold Corporation on the 23rd November. No shaft damage resulted but the kinked rope was cut.

Mechanical Failure.—(2) A 7/16th inch diameter black wire rope installed in the upcast service winze below the 10 level Hill 50 G.M. N.L. broke on the 5th July. At the time of the accident it was being tested by raising the 80 lb. kibble very quickly and stopping abruptly. Internal corrosion was evident at the break in this rope which had only been in service for two months.

When an ore loaded skip was being hoisted from the 4,000 ft. level, 2,950 feet Internal Winder, Main Shaft, Great Boulder Gold Mines Ltd., the rope failed 205 feet from the attachment. The grippers acted and suspended the skip. Examination of the rope revealed isolated internal corrosion at the point of failure.

Miscellaneous.—(2) When men were being lowered in Edwards shaft, Great Boulder Gold Mines Ltd., on the 8th March the cage hit an obstruction below the 2,250 ft. level. The cage—double decked —with six men on each deck continued under power to its destination at the 2,650 feet level. The driver was unaware of the mishap. The bottom west gate was dislodged from the cage and hung-up in the shaft. The top west gate was bowed inwards and the west side bonnet opened. Examination showed that the cage had probably hit a large stone which had slipped between worn shaft timber. The occupants of the cage received lacerations and abrasions.

An unusual mishap occurred in the Mt. Charlotte shaft, Gold Mines of Kalgoorlie (Aust.) Ltd., on the 29th June. The winder driver forgetting that there was an underground supervisor in the descending skip allowed it to descend to the 600 feet ore pocket where the skip was automatically filled with ore. Fortunately the skip-man was at the loading pocket. The skip was raised to the surface and the supervisor freed.

PROSECUTIONS.

It was found necessary to prosecute six miners during the year. All cases were successfully conducted by our Inspectors.

Two men were prosecuted for failing to wear safety belts when travelling by kibble in a winze having an inclination of more than 60 degrees from the horizontal.

Three miners were prosecuted for firing outside the prescribed times.

One man was prosecuted for firing without giving proper warning.

SUNDAY LABOUR PERMITS.

Fourteen permits, to employ labour on Sundays, were issued during the year.

Permission was given to Gold Mines of Kalgoorlie (Aust.) Ltd. to employ labour on four Sundays in the Mt. Charlotte mine. The permits covered the installation of a Cryderman mucker, rock bolting the stope, alterations to underground crusher station, and removal of the shaft pentice.

One permit was issued to North Kalgurli (1912) Ltd., to work eight Sundays placing slime fill underground to stabilise ground and ensure safe conditions.

Norseman Gold Mines N.L. were permitted to empty the underground bin and hoist the pyritic ore to the surface and so lessen the likelihood of spontaneous combustion within the broken ore.

One permit was issued to Central Norseman Gold Corporation to employ men to strip the back of the 2,200 feet level for a chute.

Two permits were issued to Pioneer Quarries (W.A.) Pty. Ltd., to cover re-screening of ballast for the standard gauge railway project and to crush rock following a major plant breakdown.

Three permits, each of three months' duration, were issued to Western Titanium N.L. The permits allowed the company to boost pit production to meet increased demand for ilmenite.

Western Mineral Sands Pty. Ltd. required a permit to re-establish production following relocation of the concentrating plant.

A permit was issued to Westralian Oil Ltd., to maintain concentrate production which was affected by a major breakdown in earth moving equipment.

AUTHORISED MINE SURVEYORS.

The Survey Board issued seven certificates during the year.

CERTIFICATES OF EXEMPTION (SECTION 46).

No certificates were issued during 1965.

PERMITS TO FIRE OUTSIDE PRESCRIBED TIMES (REGULATION 51).

No permits were issued.

PERMITS TO RISE (REGULATION 64).

Fifty-nine permits were issued for the construction of 91 rises totalling 8,461 feet. Forty-nine of these rises were advanced using the rising gig method.

ADMINISTRATIVE.

Mines Regulation Act.—An Act to amend the Mines Regulation Act was assented to on the 15th September. Section fifty-five of the principal Act was amended to read, "Any person who is guilty of an offence against this Act, for which no specific penalty is herein provided, shall be liable to a penalty not exceeding, if he is the owner, agent or manager of a mine, one hundred pounds and if he is any other person, twenty pounds for each offence."

Mining Act.—Amendments of the Mining Act assented to on the 1st October covered tailings on mining tenements, validation of tailings licenses and amendments of an administrative nature to section 322.

Coal Mines Regulation Act.—An amendment to regulation 215, dealing with payments from the accident relief fund, appeared in the *Government Gazette* dated 26th May.

Section 38 of the principal Act was amended as from the 8th November to allow persons employed cutting timber, solely for coal mining purposes, to contribute and receive the benefits of the Coal Mines Accident Relief Fund. The proclamation appeared in the *Government Gazette* dated 5th November.

Mine Workers' Relief Act.—No amendments were made to this Act during the year.

VENTILATION.

All mines throughout the State were inspected during 1965. Dust counts, temperature and air measurements were made in all working places visited. Surface inspections included metalliferous and asbestos treatment plants, rock quarries, and dry treatment plants associated with the heavy mineral sands industry.

Testing of toxic fumes and vapours associated with assay laboratories, treatment and reduction plants were continued and an investigation into the generation of hydrogen sulphide gas from explosives underground was carried out with the co-operation of of associated members of the Chamber of Mines.

Regular sampling of undiluted exhaust gases from diesel powered equipment, in use underground, was carried out at the Mt. Charlotte mine of Gold Mines of Kalgoorlie (Aust.) Ltd. At present there are six units operating plus one spare motor. All concentrations of the various gases recorded so far have been below the maximums allowable under regulations 246G and 246H of the Mines Regulation Act.

Two companies reported twelve occurrences of methane gas in metalliferous mines. Each report was fully investigated and the necessary action was taken to reduce the gas concentration. In a rise above the 2,680 sub level of the Hill 50 G.M. a miner received second degree burns to the upper portion of his body and was off work for several days as a result of an explosion of methane. Not knowing that methane was present, the miner had stopped boring to light a cigarette. No methane was detected in the underground workings of the Collie coal mines.

During the year, the total number of dust counts recorded both surface and underground was 1,226 at an average of 349 p.p.c.c.

The average count for 1964 was 319 p.p.c.c. The increase in the overall average was due to the greater number of above 1,000 p.p.c.c. samples taken in surface crushing plants. Underground, there were increases in counts taken in some cut and fill stopes where miners had failed to use ventilation equipment provided to ventilate the ends of the stopes. This problem generally occurs when a stope lift is nearing completion and the end ore pass or travelling way is covered over for several days.

Results of dust counts taken during the year are tabulated below:—

Dust Samples from	Samples Giving Over 1,000 p.p.c.c.	Total Number of Samples	Average Count
Development	4	169	298
Stoping	23	556	312
Levels	24	262	352
Surface	45	239	468
Totals	96	1,226	349

It is with pleasure that I report that for the ninth year in succession there has not been a fatal accident due to the fumes of explosives. Twenty-one alleged minor fuming accidents were reported and all were investigated.

Because of the difficulty experienced in the use of AN/FO as an explosive for sand blasting, the Lake View and Star Ltd. arranged with this Department a short series of tests using additives mixed with the AN/FO. The composition of the explosive after the additives were mixed into the AN/FO was as follows:—

	Percentage by weight.
Ammonium nitrate prills	91.72
Distillate	5.65
Water	2.26
Sodium lauryl sulphate	} 0.37
Sodium dodecyl benzene sulphonate	}
Disodium methylene dinapthalene sulphonate	}

The results of the tests showed that when small quantities of explosives are used, very little toxic fume is created after detonation and that the additives do not increase the concentration.

Aluminium Therapy.—The prophylactic treatment with aluminium powder was continued throughout the year. Random checks on the changerooms usually resulted in finding doors and windows left open during the period of powder distribution.

GROUND VIBRATION.

The Department's Sprengnether portable blast and vibration seismograph was used on five projects during the year. Vibrations from blasting operations were measured at the Mt. Charlotte gold mine at Kalgoorlie, Pioneer Quarries near the Toodyay Road at Red Hill, Water Supply trench at Wembley, and at suitable points on shore to record submarine blasting in the Port Hedland harbour and in Cockburn Sound. These tests were carried out to assist industry by advice on the use of explosives and the maximum charges that could be fired without damage to nearby structures.

GOLD MINING.

The ore treated during the year amounted to 2,530,165 tons as compared with 2,645,956 tons in the previous year. Gold recovered amounted to 656,355 fine ounces as compared with 715,481 for 1964.

Grade of ore mined was lower, recovery being 5.19 dwts. per ton as against 5.41 dwts. per ton for 1964.

The calculated value of the gold produced was £10,310,629 which included £55,081 distributed by the Gold Producers Association from the sale of 684,751 fine ounces of gold at an average premium of 19.31d per fine ounce.

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

There was a decrease in the number of men employed in the industry from 4,785 in 1964 to 4,468 in 1965. This decline was brought about by the general shortage of labour available for work in the mines. Average production of ore per man was 566 tons valued at 81.50 shillings per ton as compared with 553 tons valued at 84.59 shillings per ton for 1964. Gold recovery per man averaged 146.90 fine ounces as compared with 149.52 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 1965 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.
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	5·41
1965	2,530,165	656,355	10,310,629	81.50	4,468	314.18	5.19

TABLE E

Classification of Gold Output for 1965 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	11	....	....	....	....	....	....	....	....	....	....	11
West Kimberley	....	....	....	....	....	....	....	....	....	....	....	....
Pilbara	131	6	377	....	....	....	....	....	....	....	....	508
West Pilbara	....	....	....	....	....	....	....	....	....	....	....	....
Ashburton	....	....	....	....	....	....	....	....	....	....	....	....
Peak Hill	53	1	48	....	....	....	....	....	....	....	....	101
Gascoyne	....	1	260	....	....	....	....	....	....	....	....	260
Murchison	637	9	608	....	....	....	....	....	....	1	54,232	55,477
East Murchison	72	4	424	1	747	....	....	....	....	....	....	1,243
Yalgoo	1	....	....	....	....	....	....	....	....	....	....	1
Mount Margaret	198	2	59	....	....	....	....	....	....	....	....	257
North Coolgardie	160	17	733	....	....	....	....	1	12,987	....	....	13,880
Broad Arrow	841	9	1,145	....	....	1	1,070	....	....	....	....	3,056
North-East Coolgardie	39	3	296	....	....	....	....	....	....	....	....	335
East Coolgardie	909	14	613	1	934	....	....	....	....	4	475,444	477,900
Coolgardie	980	10	344	1	620	1	2,683	....	....	....	....	4,627
Yilgarn	590	6	524	2	1,124	....	....	....	....	....	....	2,238
Dundas	239	1	40	....	....	....	....	....	....	1	95,114	95,393
Phillips River	....	....	....	....	....	1	1,064	....	....	....	....	1,064
South-West	....	....	....	....	....	....	....	....	....	....	....	....
State Generally	4	....	....	....	....	....	....	....	....	....	....	4
Totals	4,865	83	5,471	5	3,425	3	4,817	1	12,987	6	624,790	656,355
Production, 1964	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

TABLE F

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

Mine	1965			1964			1963			1962			1961		
	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.	182,589	95,114	10.42	181,814	100,340	11·04	189,248	102,702	10·85	181,834	109,506	12·04	175,124	98,305	11·23
Eclipse Gold Mines N.L.	....	....	....	....	....	....	4,449	4,567	20·53	6,086	6,757	22·21	8,550	7,860	18·39
Gold Mines of Kalgoorlie (Aust.) Ltd.	743,364	155,057	4.17	704,369	146,366	4·16	527,680	141,837	5·38	518,747	140,919	5·43	518,244	152,964	5·90
Great Boulder Gold Mines Ltd.	387,894	92,347	4.76	425,292	111,415	5·24	450,249	118,520	5·26	450,192	121,628	5·40	452,145	129,388	5·72
Great Western Consolidated N.L.	....	....	....	....	....	....	124,062	15,159	2·44	390,462	61,352	3·14	390,700	58,477	2·99
Hill 50 Gold Mines N.L.	164,671	54,232	6.59	185,232	69,553	7·51	162,558	78,196	9·62	165,698	87,196	10·52	157,196	82,953	10·55
Lake View and Star Ltd.	619,672	151,997	4.91	683,488	164,387	4·81	690,537	168,170	4·87	694,054	172,001	4·96	681,108	166,031	4·88
North Kalgurli (1912) Ltd.	364,561	76,043	4.17	379,630	82,602	4·35	371,967	85,908	4·62	368,350	84,559	4·59	373,795	90,220	4·83
State Batteries	41,481	12,660	6·10	43,967	12,521	5·70	43,944	13,236	6·02	48,154	13,697	5·69	40,673	13,835	6·80
The Sons of Gwalia Ltd.	....	....	....	....	....	....	159,651	31,344	3·93	121,773	25,950	4·26	135,995	32,947	4·85
Timoni (Moonlight Wiluna G.M. Ltd.)	25,338	12,987	10.25	29,353	14,386	9·80	28,914	14,633	10·12	24,493	13,705	11·19	23,871	12,496	10·47
Total	2,529,570	650,437	5.14	2,633,145	701,570	5·33	2,753,259	774,272	5·62	2,969,843	837,270	5·64	2,957,401	845,476	5·72
Other Sources (excluding large Retreatment Plants)	595	3,451	116.00	12,811	10,263	16·02	16,907	17,106	20·24	19,810	10,841	10·94	27,057	13,131	9·71
Total (excluding large Retreatment Plants)	2,530,165	653,888	5.17	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
Lake View and Star Retreatment	....	....	....	....	1,048	....	....	9,222	....	....	9,094	....	....	8,339	....
State Batteries Tailings Treatment	....	2,467	....	....	2,600	....	....	2,260	....	....	2,834	....	....	3,712	....
Grand Total	2,530,165	656,355	5.19	2,645,956	715,481	5·41	2,770,166	802,860	5·80	2,989,653	860,039	5·75	2,984,458	870,658	5·83

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
Gold—		feet	feet	feet	feet	feet	feet
Murchison	Hill 50 Gold Mine N.L.	....	2,046	1,350	1,444	....	4,840
North Coolgardie	Timoni (Moonlight Wiluna G.M. Ltd.)	....	1,297	1,214	440	746	3,697
	Yilgangie Queen	....	....	....	....	1,624	1,624
East Coolgardie....	Lake View and Star Ltd.	....	19,864	2,667	4,289	29,920	56,740
	Great Boulder Gold Mines Ltd.	....	9,274	716	2,525	8,490	21,005
	North Kalgurli (1912) Ltd.	52	15,014	2,152	3,136	29,161	49,515
	Gold Mines of Kalgoorlie (Aust.) Ltd.	391	16,113	6,514	6,092	31,915	61,025
Dundas	Central Norseman Gold Corporation N.L.	....	3,514	874	2,709	35,729	42,826
	Total in Gold Mines	443	67,122	15,487	20,635	137,585	241,272
Asbestos—							
West Pilbara	Australian Blue Asbestos Pty. Ltd.	....	3,179	....	1,152	2,264	6,595
Pilbara	S. H. Stubbs—Soansville and Lionel	....	290	....	90	....	380
	Total in Asbestos Mines	....	3,469	....	1,242	2,264	6,975
Pyrite—							
Dundas	Norseman Gold Mines N.L.	....	266	170	111	3,283	3,830
Copper—							
Phillips River	Ravensthorpe Copper Mines N.L.	....	374	13	....	2,653	3,040
West Pilbara	Westfield Minerals (W.A.) N.L.	....	....	....	....	12,853	12,853
	Total in Copper Mines	....	374	13	....	15,506	15,893
Iron—							
Pilbara	Mount Goldsworthy Mining Associates	....	....	....	....	14,474	14,474
	Sentinel Mining Co. Inc.	....	....	350	....	14,335	14,685
West Pilbara	Mount Newman Iron Ore Co. Ltd.	....	....	....	....	5,316	5,316
Yalgoo	Iron Hill Pty. Ltd.	....	....	....	....	3,214	3,214
Ashburton	Dampier Mining Co. Ltd.	....	....	....	....	2,715	2,715
Yilgarn	Western Mining Corporation Ltd.	....	....	534	....	....	534
	Total in Iron Mines	....	....	884	....	40,054	40,938
Lead—							
Northampton	Nooka Lead Mine	84	243	....	....	....	327
	Total in All Mines	527	71,474	16,554	21,988	198,692	309,235

OPERATIONS OF THE PRINCIPAL MINES.

EAST COOLGARDIE GOLDFIELD.

The total ore treated in this goldfield amounted to 2,121,278 tons with a recovery of 477,900 fine ounces of gold at an average of 4.51 dwts. per ton. This output was equal to 72.8 per cent. of the gold production for the State. In the previous year 2,207,827 tons of ore averaging 4.62 dwts. were treated for a recovery of 509,984 fine ounces of gold.

Production in the *Bulong District* amounted to 100 fine ounces from the treatment of 227 tons of ore.

In the *East Coolgardie District* 477,800 fine ounces were recovered from the treatment of 2,121,051 tons of ore. Following are notes on the activities of the principal producers in the district.

Gold Mines of Kalgoorlie (Aust.) Ltd. with a production of 743,364 tons of ore for a return of 155,057 fine ounces of gold at an average recovery of 4.17 dwts. per ton was the State's leading producer. Production from the Fimiston leases was 470,174 tons yielding 116,896 ounces, from the Mount Charlotte leases 272,827 tons yielding 38,133 ounces and from tributers on the Hannans North 363 tons yielding 28 ounces.

Ore reserves as at the 31st March were 897,000 tons at 5.5 dwts. per ton plus 3,545,000 tons of free milling ore at Mount Charlotte averaging 3.4 dwts. per ton.

Placement of dry fill in old workings in the Perseverance-South Kalgurli section, together with the use of hydraulic fill in current stoping, enabled the continued mining of good grade ore in close proximity to old workings. Cut and fill mining provided 41 per cent of stope ore mined at Fimiston.

The Federal lode, off Paringa shaft, was developed on all levels down to the No. 10 level. From the Iron Duke internal shaft the Hinchcliffe cross lode was developed on the No. 13 and 14 levels. At Mount Charlotte stoping is in progress above the No. 5 level. The Reward shaft has been deepened to the No. 9 level and priority given to development and stope preparation at the No. 7 level. This work requires a new service shaft which is to be sunk to the No. 10 level horizon. At the Enterprise, diamond drilling is in progress from the No. 28 level to test the calc schist and quartz dolerite at depth.

Total development work undertaken by Gold Mines of Kalgoorlie during the year amounted to 61,025 feet made up of 391 feet of shaft sinking, 16,113 feet driving, 6,514 feet cross-cutting, 6,092 feet rising and winzing and 31,915 feet of exploratory drilling.

Auriferous pyritic concentrates railed to fertilizer works in the metropolitan area yielded, in addition to gold, the equivalent to 7,268 tons of sulphur.

Lake View and Star Ltd. produced 151,997 fine ounces of gold from the treatment of 619,672 tons at an average recovery of 4.91 dwts. per ton. The previous year's production was 164,387 fine ounces from the treatment of 683,488 tons.

Estimated ore reserves as at the 1st July were 3,385,500 short tons of an average grade of 4.77 dwts. per ton.

Development work completed during the year amounted to 26,820 feet. In addition 29,920 feet of exploratory drilling was undertaken. The work of deepening the Lake View main shaft from a depth of 2,347 feet to 2,914 feet below collar level was completed and ore is now being hoisted from the newly opened ore pocket below the 2,800 feet level. Increasing amounts of above average grade ore are expected to be mined below the 2,300 feet level in the coming year. The winder had its motor capacity increased and a system of dynamic braking installed. In conjunction with winder improvements, bottom dump skips were put into use replacing the Kimberley type.

Work continued on the enlargement of the post-cyanidation section of the treatment plant. Reconditioned Oliver filters from the Chaffers Retreatment Plant are now in operation and the first of three Brown agitators has been erected. A new power unit of 2,000 KW capacity was installed to replace the existing No. 2 power unit of 620 KW capacity.

An application has been made by the Company to the United Kingdom Treasury for permission to transfer the control and management of the Company to Australia.

Great Boulder Gold Mines Ltd. treated 387,894 tons of ore for a recovery of 92,347 fine ounces of gold, an average recovery of 4.76 dwts. per ton. During the previous year 425,292 tons yielded 111,415 fine ounces at an average recovery of 5.24 dwts. per ton.

Ore reserves at the 30th June were estimated to be 1,934,800 short tons averaging 5.18 dwts. per ton.

The Company, in common with other gold producers operating in the State, was seriously affected by the shortage of skilled miners. Labour is being recruited in the Eastern States and in the United Kingdom.

Development work totalling 12,515 feet was completed on known load channels or diamond drill intersections. This development work proceeded in all areas of the mine although the greater part of the work was concentrated in the Edwards shaft area and in the deep levels from Main Shaft Internal. Ore production is now proceeding down to 3,700 feet with development work in progress at 3,850 feet. Work is under way to establish the lowest level off the Internal shaft at a vertical depth of 4,000 feet.

Major alterations were made to primary ventilation circuits during the year. Fans were repositioned following an earth tremor in the No. 2 winze area. This tremor partially destroyed a primary fan installation and disrupted part of the ventilation circuit for some time. The repositioning of fans has improved the control of primary air circuits and reduced recirculation of air.

North Kalgurli (1912) Ltd. treated 364,561 tons of ore for a recovery of 76,043 fine ounces of gold at an average recovery of 4.17 dwts. per ton. In the previous year 82,602 ounces were recovered from 379,630 tons of ore.

Estimated ore reserves at the 30th June were 2,069,645 tons at 5.12 dwts. per ton. Completed during the year were 52 feet of shaft sinking, 15,014 feet driving, 2,152 feet cross cutting, 3,136 feet rising and winzing, and 29,161 feet of exploratory drilling.

In workings off the Kalgurli shaft the N.E.D. Lode has been developed in good values between the No. 8 and 9 levels. On the No. 18 level Main shaft a new and better than average grade ore body was developed in calc schist. This ore body is to be developed on the No. 17 level and later its extension will be sought below the No. 18 level, the present bottom working level.

Work has begun on a series of rises from the 17 level to the 13 level. It is anticipated that when these rises are completed that both the Main shaft and the Kalgurli shaft will be downcast throughout the year and that all exhaust air will pass through the fan situated at the Union Jack shaft. At present the Main shaft downcasts during the winter months and is an upcast for the remainder of the year. Repositioning of fans at the Croesus shaft has increased airflows in that section.

The *Daisy* mine at Mount Monger continued as a high grade small producer. 1,180 tons of ore treated at the Kalgoorlie State Battery yielded 934 fine ounces of glod. Two winzes sunk below the No. 7 level have proved the downward continuation of ounce values to 95 feet.

DUNDAS GOLDFIELD.

The production of 95,393 fine ounces of gold from the treatment of 182,714 tons of ore represented 14.5 per cent. of the State's total production. In the previous year 182,515 tons of ore yielded 100,864 fine ounces.

Central Norseman Gold Corporation N.L. treated 182,589 tons for a recovery of 95,114 fine ounces. Gold recovery was at the rate of 10.42 dwts. per ton as compared with the previous year's recovery of 11.04 dwts per ton when 181,814 tons yielded 100,340 ounces.

Reserves of ore at the 23rd May were estimated to be 675,000 tons averaging 10.5 dwts. per ton.

Work was continued off the Regent and Princess Royal shafts and the surface winze north of the Royal. Total development amounted to 7,097 feet which included 3,514 feet driving, 874 feet cross-cutting, 1,909 feet rising and 800 feet winzing. A geochemical survey of the southern Norseman area was commenced to test for trace element dispersion in the soil.

Off the Regent shaft, stoping operations were carried out between the No. 16 and 32 levels with most ore coming from stopes above the 16 and 19 levels. Level development was confined to the 22 and 23 levels. A winze sunk approximately 700 feet below the No. 29 level was completed and an ore pocket formed near the bottom in preparation for level development to test that horizon.

Off the Princess Royal shaft, stoping was confined to stopes above the No. 6 and 7 levels and driving on the No. 22 level. The surface winze north of the Princess Royal shaft was expected to cease production before the end of the year as the programme consisted of remnant extraction between the 4 and 6 levels. Towards the end of the year an extension of the ore body was discovered off the No. 6 level stope and work is continuing in good values.

Prospectors were not very active in the Dundas goldfield during the year and in an endeavour to increase interest in this activity the Department purchased a compressor and rock drill outfit for use by prospectors in this field.

MURCHISON GOLDFIELD.

168,226 tons of ore were treated in this goldfield for a return of 55,477 fine ounces of gold. This production was equal to 8.5 per cent of the State's total. In the previous year 69,553 ounces were obtained from the treatment of 185,232 tons.

Gold output from the various tenements in the *Cue and Day Dawn Districts* amounted to 221 fine ounces from the treatment of 587 tons. The most successful producer was the New Rand at Reedys which returned 122 fine ounces from 528 tons crushed at the State Battery.

In the *Meekatharra District* 968 ounces were recovered from the treatment of 2,808 tons of ore. The main producers in the district were the Poplar at Nanadie Well with a return of 153 ounces from 95 tons and the Halcyon at Meekatharra with 124 ounces from 2,401 tons. State Battery sands treatment yielded 324 fine ounces of gold.

The *Mount Magnet District* produced 54,288 fine ounces of gold from the treatment of 164,831 tons of ore. The principal producer was *Hill 50 Gold Mines N.L.* with 54,232 from 164,671 tons. Average recovery was 6.59 dwts. per ton which was nearly one pennyweight less than the previous year's average of 7.51 dwts. when 69,553 ounces were recovered from 185,232 tons.

Ore reserve at the 29th June was estimated as 808,900 tons at 5 dwts. per ton.

Development work completed during the year included 2,046 ft. driving, 1,350 feet crosscutting, 1,115 feet rising and 329 feet winzing. Major work undertaken underground during the year consisted of developing the Nos. 12 and 13 levels, completing the sinking of the exploratory winze to 589 feet below the No. 11 (2,460 ft.) level and crosscutting on the Nos. 12 and 13 levels to the site of a proposed internal shaft to be sunk below the 12 level.

At the Morning Star a headframe and winder were installed. The shaft was renovated and the mine dewatered to the No. 4 level where electric pumps were installed. An inclined winze below this level was dewatered, regraded and rerailed to the 657 feet horizon.

In order to handle future ore from the Brown Hill and Morning Star mines a ramp, bin and crusher were installed adjacent to the treatment plant.

NORTH COOLGARDIE GOLDFIELD.

Production from this goldfield amounted to 13,880 fine ounces of gold recovered from 29,387 tons of ore averaging 9.45 dwts. per ton. As a comparison the production for the previous year was 17,858 ounces from 34,860 tons averaging 10.25 dwts. The output from this goldfield represented 2.1 per cent of the State's total.

In the *Menzies District* the leading producer was *Moonlight Wiluna Gold Mines Ltd.* operating the Timoni mine at Mount Ida. From this mine 12,987 fine ounces were obtained from 25,338 tons averaging 10.25 dwts. recovery per ton.

Development work for the year included 1,297 feet driving, 1,214 feet crosscutting, 369 feet winzing and 71 feet rising. The southern extension of the ore body has now been largely mined out and latest developments have been concentrated on a northern extension. Payable ore has been developed on both the No. 4 and No. 6 levels. The limits of this shoot has not yet been established but it appears that it is of comparable grade to the southern extension. At the 30th June the estimated ore reserve was 33,818 tons averaging 9.9 dwts. per ton.

Smaller producers in the district won 224 ounces from 2,790 tons.

In the *Ularring District* the production was 450 fine ounces of gold recovered from the treatment of 764 tons of ore. The principal producers were the *Oakley* with 209 ounces from 220 tons, and the *Four Mile* with 90 ounces from 9 tons.

Only 65 fine ounces of gold were reported from the *Niagara District*. Increased mining activity in the district hinges on the results obtained from geophysical work being undertaken by Central Norseman Gold Corporation at Kookynie.

In the *Yerilla District* 336 tons were treated for a return of 154 fine ounces of gold. Practically all of this production was from the *Yilgangie* mine at Yarri with a return of 119 ounces from 197 tons. Exploratory diamond drilling of the Yilgangie Queen was unsuccessful and this mine closed down during May. It had been a consistent producer of ounce values for a number of years.

COOLGARDIE GOLDFIELD.

During 1965, 3,946 tons of ore were treated for a return of 4,627 fine ounces of gold. In the previous year 4,520 tons yielded 4,007 fine ounces.

The *Little Nipper* at Ryans Find produced 2,683 fine ounces of gold from 27 tons of ore. Included in this return was 2,020 ounces won from specimen stone treated in the Berdan pan at the Coolgardie State Battery. At the beginning of the year, the syndicate ceased following two separate enrichments at the bottom of the mine (about 100 feet depth) and commenced a south drive at 50 feet under a flat shear zone which had cut off the three high grade ore shoots above. Further development work revealed another rich zone which was developed by sinking on it to about 150 feet below the surface.

Paris Gold Mines Pty. Ltd.—Although work ceased on this mine early in 1964, a late return from gold-copper concentrates forwarded to Japan was to hand in January. This return showed a recovery of 620 ounces of gold and 1,716 fine ounces of silver. The copper content was credited to 1964 production.

Tributers mining a block of ore near the Barbara shaft, of Gold Mines of Kalgoorlie (Aust.) Ltd., raised 739 tons of ore which yielded 155 fine ounces of gold.

At Spargoville, two week-end prospectors discovered rich ore by loaming. They recovered 380 ounces from specimen stone and a further 45 ounces from 15 tons of ore. This find attracted others to the area.

Among the smaller producers in the Coolgardie Goldfield the more successful returns were from the *Rayjax* with 71 ounces from 53 tons, the *Glenloth* at Burbanks with 68 ounces from 174 tons, and the *Jackpot* with 43 ounces from 102 tons.

BROAD ARROW GOLDFIELD.

Total production for the year was 3,056 fine ounces of gold recovered from the treatment of 15,635 tons of ore.

The Ora Banda Mining Syndicate mining on the *Gimlet South* leases crushed 12,633 tons for a return of 1,070 fine ounces of gold. Preparations are now in progress to resume underground mining because of low values in the open cut.

At Grants Patch 204 tons from the *Prince of Wales* yielded 388 fine ounces and the *Coronation* 151 ounces from 194 tons of ore. The crushings were obtained from mining of remnants in the old Ora Banda Amalgamated mine.

The *Rona Lucille* mine at Paddington was re-opened by a part time prospector who obtained 282 ounces from 114 tons of ore. Good returns were also obtained from the *Bellevue South*, near Black Flag, with 167 ounces from 91 tons and the *Pride* at Bardoc with 98 ounces from 99 tons. The Ora Banda State Battery treatment of sands yielded 600 fine ounces of gold.

YILGARN GOLDFIELD.

Gold production in the Yilgarn declined further to 2,238 fine ounces recovered from 2,757 tons. However, mineral potential is high with large deposits of iron ore at Koolyanobbing, Bungalbin and Mount Jackson and gypsum at lakes Seabrook and Brown.

The *Frances Furness* at Marvel Loch produced 509 fine ounces of gold from the treatment of 1,253 tons of ore. At present the lease has been exempted from mining conditions and water allowed to accumulate in the workings. The presence of molybdenite in the pegmatite has aroused interest and the mine is reported to be under option to Hill 50 Gold Mine N.L.

The *Radio* mine in the Golden Valley centre reported the production of 615 fine ounces of gold from 592 tons of ore. Mining for gold has ceased and the plant is at present being used to crush rock for roadworks. Cost of production influenced this policy as well as wet and dangerous ground and the absence of suitable labour.

Plant cleanup around *Great Western Consolidated N.L.* at Bullfinch yielded 352 ounces from 17 tons.

At Parker's Range, the *Constance Una* produced 108 ounces from 108 tons. A new shoot of ore has been discovered in this mine and rich crushings are expected during 1966.

EAST MURCHISON GOLDFIELD.

Ninety four per cent of the total production, of 1,243 fine ounces of gold recovered from 2,026 tons of ore, was obtained from mining operations at the Goanna Patch on Wildara Station in the Lawlers District.

At the *Mangilla* mine the quartz reef has been developed to 60 feet and laterally for about 150 feet. Output for the year was 747 fine ounces from 652 tons. The *Tahmoo* produced 200 fine ounces from 603 tons. At this mine, ore from the original shaft is now exhausted and exploratory shaft sinking on the line of lode is being undertaken some 100 feet further North.

Central Norseman Gold Corporation N.L. has taken over Western Mining Corporation's interests at the Goanna Patch and have prospected the area by shallow drilling and surface sampling. Their mine the *New Darlot* produced 196 fine ounces from 526 tons.

The area continued to attract the attention of prospectors, but no worthwhile new finds were made.

PHILLIPS RIVER GOLDFIELD.

The only producer in this field was *Ravensthorpe Copper Mines N.L.* with 1,064 fine ounces of gold. All of the gold was recovered from 2,052 tons of copper concentrates exported to Japan. These concentrates also contained 465 tons of copper and 3,136 fine ounces of silver. Total tonnage treated at Ravensthorpe was 48,429 tons which included 11,177 tons of sand and residues from Two Boys, Smelter and Harbour View.

Mining was concentrated on the No. 5 level *Elverdton* where developments have opened up good ore north and south of the shaft.

PILBARA GOLDFIELD.

Nine hundred and twenty tons of ore obtained in this goldfield yielded 508 fine ounces of gold. The decline in gold production was brought about by the increased activity in the iron ore, manganese and tin deposits in this field.

The principal producers were the *Kitchener* at Bamboo Creek with 197 fine ounces from 28 tons, the *Prophecy* at the same centre with 91 fine ounces from 229 tons, and the *Birthday Gift* at Pilgangoora with 62 fine ounces recovered from 66 tons of ore.

NORTH EAST COOLGARDIE GOLDFIELD.

Gold production totalled 335 fine ounces recovered from 661 tons of ore. The only producers of note were the *Kanowna Red Hill* with 162 fine ounces from 235 tons, the *New Kanowna* with 69 fine ounces from 11 tons, and 65 fine ounces from 187 tons of ore from *Rowes Find* situated some 20 miles N.E. of Karonie.

GASCOYNE GOLDFIELD.

The *Star Mangaroon,* with 260 fine ounces of gold recovered from 98 tons crushed at the Meekatharra State Battery, was the only producer in this goldfield.

MOUNT MARGARET GOLDFIELD.

There was very little activiy in this goldfield which produced 257 fine ounces of gold from 1,213 tons of ore. Most of this production amounting to 212 fine ounces from 1,134 tons came from the Mount Malcolm District.

PEAK HILL GOLDFIELD.

During the year, 101 fine ounces of gold were recovered from 1,304 tons of open cut ore, dump material and sands from the old Peak Hill mine.

Other sources within the State produced 16 fine ounces of gold.

MINERALS OTHER THAN GOLD.

The production of minerals, other than gold, for 1964 and 1965 is shown in the table below.

MINERAL OUTPUT EXCEPT GOLD

Mineral	1964		1965	
	Tons	Value	Tons	Value
Asbestos—		£A		£A
Chrysotile	536.19	43,681	402.00	28,839
Crocidolite	10,614.14	1,062,100	9,279.94	873,040
Barite	171.70	683	750.75	3,003
Bauxite	370,784.00	3,531,720	486,718.00	4,454,040
Bentonite	676.28	1,571	921.45	1,819
Beryl	79.84	9,038	13.08	1,445
Building Stone	1,058.85	5,814	1,286.00	7,989
Clays	103,947.85	107,048	224,117.50	173,357
Coal	987,419.70	2,339,467	993,740.80	2,204,986
Copper—				
Ore and Concentrates	4,618.69	275,878	2,051.50	127,460
Fertiliser grade	2,196.69	125,985	1,078.76	49,617
Felspar	1,386.00	9,763	1,384.00	9,744
Fuller's Earth	114.00	456	63.00	267
Glass Sand	10,047.00	7,029	9,259.00	6,084
Gypsum	44,998.12	53,779	46,607.00	44,577
Ilmenite	330,832.70	1,538,175	392,891.22	1,926,188
Iron Ore—				
Exported	1,280,864.00	1,270,189	2,240,939.00	2,222,269
For Pig	82,843.00	1,101,608	65,623.00	935,479
Lead Ore and Concentrates	3,354.17	92,632	4,877.93	196,319
Leucoxene	643.19	11,894	484.00	10,806
Limestone	31,639.00	42,650	565,830.00	313,686
Lithium Ore—				
Petalite	208.00	1,591	310.00	2,371
Spodumene	51.54	1,055	....	....
Magnesite	1,574.24	10,020	199.08	1,588
Manganese	38,823.81	457,338	100,208.20	1,075,926
Monazite	1,317.19	54,475	1,068.00	52,151
Ochre	323.51	1,942	186.65	1,120
Phosphatic Guano	....	....	15.00	150
Pyrite	58,396.00	368,782	59,179.94	384,122
Rutile	825.51	25,771	225.00	7,994
Scheelite	4.31	1,174	....	....
Silver (fine oz.)	245,557.97	143,842	290,622.68	170,206
Talc	5,431.69	75,002	7,087.79	102,705
Tantalo-Columbite	14.57	13,288	9.87	8,873
Tin Concentrate	637.04	620,391	675.58	778,257
Zircon	20,068.72	195,637	27,879.67	375,134
Totals	....	13,601,468	....	16,551,611

Brief notes on mineral production are given below.

ASBESTOS.

Chrysotile—Development work at Soansville opened up some very promising fibre which could not be mined because of the shortage of suitable labour. The plant at the Comet mine, Marble Bar treated 1,700 tons of ore from this source. At Lionel, 2,360 tons of ore were carted to the Comet before labour shortages caused cessation of mining at this centre. Output of fibre from the mill was 373 tons valued at £28,228. Other sources in the Pilbara produced 29 tons of chrysotile.

Crocidolite—Australian Blue Asbestos Ltd. at Wittenoom produced, from 173,877 tons of ore, 9,280 tons of fibre valued at £873,040. The average number of men employed throughout the year was 343 made up of 165 surface and 175 underground employees.

Exploratory diamond drilling in the Eastern Creek area has indicated that fibre exists in economic quantities and plans for a suitable mine layout are being prepared. In the Colonial mine, the longwall method of stoping has been developed to a stage where its general application throughout the mine is being considered. Development work completed during the year included 3,179 feet of driving, 1,152 feet of rising and 2,264 feet of exploratory drilling.

BARITE.

From the deposit at Chesterfield near Meekatharra, Universal Milling Co. Pty. Ltd. obtained 751 tons of barite valued at £3,003 f.o.r. The barite occurs as a steeply dipping reef twelve to twenty-four inches wide.

BAUXITE.

Alcoa of Australia Pty. Ltd.'s refinery at Naval Base treated 486,718 tons of bauxite won by Western Aluminium N.L. from the deposit in the rifle range area at Jarrahdale. This bauxite yielded 148,468 tons of alumina having a nominal value of £4,454,040.

Preparations are being made to obtain bauxite from other deposits in the vicinity as progress is rapid over the large shallow deposits. To date no excavation has exceeded 30 feet, the average being 15 feet. Another crusher is to be installed at Jarrahdale to cope with the increased throughput and to regulate product size.

BENTONITE.

Bentonite production from the Cunyidi-Marchagee area, about 150 miles north of Perth, was 921 tons valued at £1,819 f.o.r. These lake deposits are only worked during the summer months.

BERYL.

Thirteen tons containing 149 units of beryllium oxide valued at £1,445 were obtained from claims in the Yalgoo Goldfield and from Londonderry in the Coolgardie Goldfield. There was no production reported from the Pilbara and West Pilbara Goldfields.

BUILDING STONE.

One hundred and six tons of granite facing stone were reported as being produced at Watheroo; 245 tons of quartz from Gibraltar near Coolgardie; 221 tons of sandstone from Mount Barker; 529 tons of spongolite from Ravensthorpe, and 185 tons of slate from Mundijong. This production relates to holdings under the Mining Act and would only represent a small portion of the State's output.

CLAYS.

Reported clay production for the Metropolitan area, Clackline, Glen Forrest, Mount Kokeby, Kalgoorlie and Goomalling totalled 224,117 tons valued at £173,357. The apparent doubling of output as compared with 1964 was brought about by including clays obtained from private property and not previously reported. Output is still in excess of the above tonnage as all output is not reported to this Department. Some shale would be included with the clays used by the brickmaking industry.

COAL.

The total output from all mines in the Collie Coalfield was 993,741 tons valued at £2,204,986 at the pithead. Open cut production of 485,481 tons represented 48.8 per cent of the field's output.

The *Griffin Coal Mining Co. Ltd.* operating the Hebe mine and the Muja open cut produced 534,947 tons. The Hebe which was producing approximately 10,000 tons per fortnight and which contributed 49,466 tons to the 1965 output ceased production early in April as a result of an inrush of water which flooded the mine up to the level of the No. 4 Left District Sump Bord and inbye workings. All worthwhile equipment was salvaged from the higher districts of the mine and from the main tunnels above No. 7 Left District. Pumping has reduced the level of the water to below the No. 5 Left Belt Bord and preparations are in hand to construct a bore to accommodate a submersible pump.

Most of the 485,481 tons of coal won from the Muja open cut was taken from the Hebe seam. Other seams worked were the Centaur (35,033 tons) and the Galatea (22,585 tons). Excluding the removal of dumps and excavations for roads and other ancillary purposes, the quantity of overburden removed to uncover coal was 2,130,379 cubic yards in the solid. Overburden removed to coal produced based on a coal specific gravity of 1.28, was 4.2 to 1. Coal from the open cut was first delivered to the Muja power station on the 9th August and towards the end of the year approximately 5,000 tons of coal per week were being transported.

Western Collieries Ltd. produced 458,794 tons of coal during 1965. A record output of 367,384 tons from the Western No. 2 mine, exceeded the previous year's output by over 50 thousand tons. In this mine the Nos. 1 and 2 dip headings of the main development slants were driven forward 312 and 332 yards respectively. The plan distance from the main entry portal to the faces of these headings is approximately 95 chains and their vertical depth from the surface is 430 feet. The seam in this area is 11 feet to 12 feet in thickness. It is intended that a main sump will be constructed at a position approximately 8 chains in front of the present position of the main slants and that an S.E.C. bore hole will be put down over this area.

Western Collieries Western No. 4 mine produced 91,410 tons for the year. This also was a record for this mine. A heading, to connect the lower or Wallsend seam to the upper or Moira seam, was driven through the fault in No. 10 Bord in the East portal. Reasonably good progress was achieved in the drivage of the two main east portal development headings. Inferior roof conditions, slips and minor faults are features of the current workings in the south portal.

COPPER.

Ravensthorpe Copper Mines N.L. produced 2,052 tons of concentrate from 48,429 tons of ore, sands and residues containing 46,518 units of copper valued at £127,460 f.o.b. Esperance. These concentrates also cotained 1,064 fine ounces of gold and 3,136 fine ounces of silver. Mining was concentrated on the No. 5 level Elverdton where developments have opened up good ore north and south of the shaft. During the year the Flag mine at Kundip was unwatered and a surface and underground diamond drilling programme carried out. Diamond drilling at the Elverdton, Flag and Marion Martin mines totalled 2,653 feet. The average number of men employed during the year was 71.

Production of copper ore, for use as a trace element in fertilisers, was 1,079 tons as compared with 2,197 tons for the previous year. Grade was also lower at 14.92 per cent Cu as compared with the 1964 average grade of 17.99 per cent Cu.

The *Thaduna Copper Mining Co. Pty. Ltd.* reported a production of 504 tons of concentrate averaging 14.74 per cent Cu valued at £25,313. High grade sulphide ore has been struck in sumps at the bottom of the 40 feet deep open cuts. This discovery may transform the mine from a copper carbonate producer to a copper sulphide producer. Geophysical prospecting and diamond drilling of the deposit by New Consolidated Goldfields was continued for most of the year.

Other notable producers of copper ore were *R. Lee* at Thaduna with 115 tons of 20.82% ore valued at £8,698; *T. Lee* at Yannery Hills with 138 tons of 18.95% ore valued at £7,062; *M. Alac* at Ilgarari and Kathleen Valley with 36 tons of 21.54% ore valued at £2,567, and *G. Motter* at Horseshoe with 111 tons of 10.16% ore valued at £2,326.

FELSPAR.

Australian Glass Manufacturers Co. Pty. Ltd. reported the production of 1,384 tons from their quarry at Londonderry. In addition 310 tons of petalite valued at £2,371 and 5½ tons or beryl valued at £636 were obtained by hand sorting.

FULLERS EARTH.

Marchagee production totalled 63 tons valued at £267.

GLASS SAND.

Production from the Lake Gnangara deposit amounted to 9,259 tons valued at £6,084.

GYPSUM.

Plaster manufacturers obtained their supplies of gypsum from Yellowdine, Lake Brown, Lake Cowcowing and Lake Cowan. Plaster of paris reported as manufactured was 21,739 tons from 31,036 tons of gypsum. The sources of 12,501 tons of gypsum used in cement manufacture were Yellowdine and Nukarni. Total production for the year, including 32 tons for agricultural purposes, was 46,607 tons valued at £44,577 f.o.r.

ILMENITE, LEUCOXENE, MONAZITE, RUTILE, ZIRCON.

Sales of ilmenite totalled 392,891 tons valued at £1,926,188. This output represents nearly three times the 1963 production of 136,880 tons. Minerals associated with ilmenite returned £446,085 to the producers.

Western Titanium N.L. at Capel produced 147,412 tons of ilmenite assaying 54.29 per cent titanium dioxide, 379 tons of leucoxene, 520 tons of monazite, 225 tons of rutile and 12,427 tons of zircon. Mining was concentrated in an area south of the treatment plant where a 480 feet wide face 18 feet deep was advanced in a southerly direction. Some explosives were used to break up hard rock which was sitting on top of the sands to be sluiced. The construction of a new wet concentrating plant incorporating Reichhardt cones was commenced during the year. Preparations are in hand to increase the plant capacity to 200,000 tons per year.

Westralian Oil Ltd. produced 69,826 tons of ilmenite assaying 59.76 per cent TiO_2, 105 tons of leucoxene, 547 tons of monazite and 12,755 tons of zircon from the Yoganup deposit. The Westralian Mining and Oilfield Services continued to do the mining for the company 'till early in 1966. All ore delivered by the contractor was treated at the wet concentrating plant at Yoganup and the concentrates then carted to the dry treatment plant at Capel for final separation of the valuable minerals from the gangue.

Western Mineral Sands Pty. Ltd. at Capel produced 91,679 tons of ilmenite assaying 53.69 per cent TiO_2. The skid mounted wet concentrating plant has been set up at the centre of the 1,400 feet wide ore body and the sands pumped to it from the operating pit. About 52,000 tons of sand per four weekly period is handled by loaders which deliver to a cleaning screen and bin in the pit. Included in the wet plant is a 3 stage double Reichhardt cone.

Cable (1956) Ltd. at Bunbury produced 49,262 tons of ilmenite assaying 55.32 per cent TiO_2, 1 ton of monazite and 2,697 tons of zircon. No basic alterations were made to the dry treatment plant except that the plant building was extended to allow for equipment required for monazite and zircon extraction.

Ilmenite Pty. Ltd. operating at Wonnerup near Busselton produced 34,712 tons of ilmenite assaying 53.58 per cent TiO_2. Work was commenced on Sussex Location 7 near the Sabina River in addition to the work previously undertaken along the coastal strip adjacent to the Wonnerup Inlet.

IRON ORE.

During 1965, *Australian Iron and Steel Ltd.* shipped to the Eastern States, 2,240,939 tons of iron ore averaging 64.28 per cent Fe. The nominal value of this output was £2,222,269. Production at Koolan Island commenced early in the year and ore shipped from Koolin totalled 1,059,648 tons. Cockatoo Island was responsible for the remaining 1,181,291 tons of ore produced. The average total number of persons employed by A.I.S. on the two islands totalled 379.

The *Charcoal Iron and Steel Industry* at Wundowie obtained 65,623 tons of ore from the Koolyanobbing deposit. Pig iron produced was 40,673 tons valued at £935,479. The industry also uses limestone quarried at Beaconsfield and quartz mined near the Toodyay Road adjacent to Wundowie.

Throughout the year there was continued activity at the various iron deposits and port sites. At Koolanooka Hills (near Morawa) the partnership of Western Mining Corporation, Hanna Mining and Homestake prepared for iron ore export in 1966. Work in progress at the end of the year included crushing plant erection, construction of roads, site preparation, office and workshop construction and construction of the spur railway line near Morawa. The ship loading installation at No. 4 berth Geraldton was nearing completion.

Operations at Mount Goldsworthy had reached an advanced stage at the end of 1965. Dredging operations at Port Hedland had been delayed by the inability of the dredge Alameda to cut through the limestone shelves encountered on the harbour bed.

During March 1965 operations were started at King Bay for the purpose of establishing the port of Dampier which will provide stockpiling facilities, screening and ship loading plant. Construction of the 178 mile standard gauge railroad to Mount Tom Price was well advanced by the end of the year as well as the crushing, screening and loading facilities at the deposit.

A sample parcel of 12,000 tons of limonitic ore was broken from the Robe River deposits and was carted to a stockpile near Port Samson for shipment early in 1966. There was also continued activity around the deposits at Mount Newman, Nimingarra, Mount Gibson, Koolyanobbing and Mount Jackson.

LEAD.

Lead concentrate sales from the Northampton mineral field amounted to 1,254 tons valued at £104,628. The Nooka was the main producer with 773 tons of concentrate valued at £61,333. These concentrates contained 546 tons of lead. The Nooka shaft was sunk a further 84 feet and a new level established at 276 feet.

At the Mary Springs lead mine a west crosscut, driven off the south end of the 100 feet level drive, intersected ore up to 5 feet wide which was in such quantity and quality that it was directly drummed for sale. Production from this mine was 205 tons valued at £19,059.

The Devonian mine in the West Kimberley goldfield produced 3,624 tons of lead-zinc ore valued at £96,696 f.o.r. Derby. This ore contained 487 tons of lead and 1,010 tons of zinc. In addition the ore contained 7,966 fine ounces of silver valued at £4,670. At the close of the year mining had been suspended through lack of ore and further mining of the deposit will depend upon successful exploration.

LIMESTONE.

Reported production of limestone was 565,830 tons valued at £313,686. This phenomenal increase as compared with 31,639 tons for 1964 was brought about by including in the statistics limestone, obtained from private property, not previously reported. Total annual production would still exceed the production quoted above.

Limestone for cement manufacture was obtained from the South Coogee area where it is ripped by bulldozers and pushed into heaps for ease of loading. Building stone was obtained from deposits at Wanneroo and Beaconsfield. Limestone used as a flux by the Charcoal Iron and Steel industry was mined, crushed and screened at Beaconsfield. Wanneroo and Marmion are the principal areas where rubble is obtained for road construction.

LITHIUM ORE.

Australian Glass Manufacturers Co. Pty. Ltd. operating the felspar quarry at Londonderry obtained 310 tons of petalite by hand sorting.

MAGNESITE.

Sale of 199 tons of magnesite stockpiled at Esperance yielded £1,588. No work was carried out at the deposit, near Ravensthorpe, during the year.

MANGANESE.

Exports from Port Hedland totalled 67,154 tons of 51 per cent Mn ore valued at £747,915 f.o.b. The principal producer, *Mt. Sydney Manganese Pty. Ltd.*, employing an average of 43 men, sold 54,973 tons obtained from three mineral claims at Woody Woody. *Westralian Ores Pty. Ltd.'s* Pilbara operations at Woody Woody and Skull Springs resulted in the sale of 9,926 tons valued at £114,727. This company also mined manganese at Horseshoe and shipped from Geraldton 3,498 tons of lower grade material valued at £32,531. The *Broken Hill Pty. Ltd.* obtained 29,517 tons of 48 per cent Mn ore valued at £295,170 from a deposit in the Mount Frazer area in the Peak Hill goldfield. This deposit has now been worked out and the company's operations transferred to M.L. 64 P an area some eleven miles south.

OCHRE.

The *Universal Milling Co. Pty. Ltd.* produced 187 tons of red oxide from the Weld range deposit in the Murchison.

PHOSPHATIC GUANO.

Reported production from the Jurien Bay area was 15 tons valued at £150.

PYRITE.

Norseman Gold Mines N.L. broke a total of 85,068 long dry tons of ore during the year of which 85,031 tons were treated in the heavy media separation plant, followed by 73,404 tons of this product treated by flotation to give 37,385 tons of concentrates estimated to contain 17,900 tons of surphur. Railed to superphosphate works in the metropolitan area were 36,905 tons of concentrates containing 17,597 tons of sulphur valued at £293,272 f.o.r. Norseman.

Gold Mines of Kalgoorlie (Aust.) Ltd. forwarded to works at Fremantle 22,275 tons of auriferous pyritic concentrate containing 7,268 tons of sulphur valued at £90,850.

SILVER.

Silver as a by-product of gold, lead-zinc, and copper mining amounted to 290,623 fine ounces valued at £170,206.

TALC.

Three Springs Talc Pty. Ltd. reported the production of 7,088 tons from open cutting operations at Three Springs.

TANTALO-COLUMBITE.

Ten tons of concentrate, containing 406.96 units of Ta_2O_5 valued at £8,873, were produced during 1965. The producing centres were Greenbushes with 237.19 units, Warda Warra in the Yalgoo goldfield with 158.21 units and the Pilbara with 11.56 units. The output from Greenbushes was obtained during tin mining operations.

TIN.

Production for the year was 676 tons of concentrate containing 468.27 tons of the metal valued at £778,257. Tin producers in the Pilbara were responsible for 645 tons of the concentrate. Principal producers were *Cooglegong Tin Pty. Ltd.* with 208 tons recovered at a rate of 2.4 lbs. concentrate per cubic yard treated, *Pilbara Tin Pty. Ltd.* with 139 tons recovered at the rate of 3.8 lbs. per cubic yard, *J. A. Johnston and Sons* at Eleys with 115 tons, *H. V. Leonard* at Moolyella with 85 tons, and M. R. Edwards at Moolyella with 39 tons. All tin producers had a successful year and a considerable amount of attention was given to tin bearing areas by mining companies. Good rains early in 1966 have provided all producers with adequate water supplies.

In the Greenbushes field the only producer of note was the *Vultan Syndicate* with a production of 30 tons of concentrates valued at £33,877. *Greenbushes Tin N.L.* transported the Jim Crow dredge from Victoria and reassembled it at Greenbushes, constructed shore based wet and dry treatment plants and prepared their area for production in 1966.

J. K. N. LLOYD,
Assistant State Mining Engineer.

APPENDIX No. 1.

State Mining Engineer:

REPORT ON DRILLING ACTIVITIES FOR YEAR ENDED 31st DECEMBER, 1965.

During the year under review a total of 14,330 feet has been done by the drilling section. This is an increase of 535 feet on the footage completed in 1964.

Every machine operated by the drilling section was in use for some part of the year and at one stage during the year eleven rigs owned by the Department were out in the field together. Three of the rigs were hired to various drilling contractors and the footages done by these machines does not show in this return.

During the year a new Mayhew 2000 drilling rig mounted on an International truck arrived from overseas but has not yet been delivered to the drilling section. This rig and ancillary equipment together with an auxiliary pump is valued at $84,000. Its rated capacity is 2,000 feet of 6 in. hole.

Other noteworthy equipment purchased during the year under review is:—

(1) An axial flow vertical turbine pump made by Ornel having a capacity of 20,000 gallons per hour from 500 feet. This pump is powered by a 100 h.p. air cooled Deuty diesel. The value of this plant was $10,236.

(2) A helical rotor positive displacement pump manufactured by the Mono Pump Coy. The primary purpose of this pump is for handling drilling mud. Its construction makes it particularly suitable for this application, due to its resistance to abrasion freedom from valves and cylinder clearances.

(3) A mobile 100 ton capacity hydraulic jacking unit for pulling stuck casing.

(4) A mobile crane with a capacity of 3 tons principally engaged in handling plant and casing.

Amongst other plant coming into the store were two new Land Rover vehicles; a 30 cwt. truck, two 2 Berth caravans and a 1½ c. ft. concrete mixer. In the heavy transport section we have five Leyland trucks ranging in age from 13 years to 6 years. Consideration should be given to the replacement of the older vehicle and additional heavy transport will be necessary to service the new rigs should they all be engaged together.

Rig No. 2 (Failing M1) completed 5,371 feet in three holes during the year. This machine was operated by J. Grill under contract arrangements to the Department. The first hole was done in a Water Resources Survey at Wanneroo. The second at Bullsbrook and the third was at a depth of 1,566 feet near Guilderton at the close of the period. The plant operated efficiently for the year but owing to insufficient pump volumes it was at the limit of its capacity nearing the bottom of the holes around the two thousand feet mark.

Rig No. 3 (A.3000). No footage was recorded for this machine in the drilling section. It is on hire to the Canadian Southern Cross Mines N.L. near Northampton. This machine is fitted with a Ford engine and Bedford parts which are now obsolete and considerable delay has arisen in obtaining replacements for worn parts.

Rig No. 4 (A.2000) drilled 395½ feet in four holes on dam site investigations for the Metropolitan Water Supply at South Dandalup. The majority of this footage was in granite or laterite.

Pressure testing of the formation drilled, to determine water loss, was carried out as drilling progressed.

Rig No. 5 (A.2000) was hired to Associated Diamond Drillers. It was used on iron deposits at Mt. Gibson near Wubin. Footage figures have not been returned from this operation.

Rig No. 6 (A.2000). This plant was hired to Western Mining Corporation for some months engaged on drilling for iron out of Morawa. Footages done at this centre were not reported. For the drilling section 609½ ft. were completed. At Merredin 208½ ft. in 6 holes were done investigating the properties of granite in local outcrops as a possible quarry site.

At the request of the P.W.D. four hundred and one feet in 7 holes were completed at Hopetoun investigating the ground water resources. Initially this programme was commenced with the Gemco auger drill but it was soon found that this plant had insufficient weight to penetrate the hard capstone occurring in the area.

The potable water occurrences were considered to be basins of fresh underlain by more saline waters and this proved to be the case. When the Gemco could not drill the formations encountered, geological advice was that normal drilling techniques utilising water as a cooling and flushing agent should not be used. It was considered that the introduced drilling water would interfere with the testing programme of the underground water. With this in view it was decided to drill using compressed air as the cooling and flushing medium. A suitable compressor to give an annular rising velocity to the cuttings of not less than 3,000 feet per min. was obtained.

This proved to be quite successful in all holes. The method is dusty and dirty for the driller and a suction fan and cyclone would be needed for an extensive programme.

When the water table is encountered the cuttings tend to build up on the moist section near the water contact and it was necessary to drill upwards to get out of the hole on some occasions. Hole No. 25 was drilled to forty feet below water level the compressed air blowing the water from the hole.

Rig No. 7 (F20). Eight hundred and thirty-six feet of drilling in nine holes were completed by this machine in two interesting assignments. At the request of the P.W.D. four holes were drilled vertically through the concrete wall of the Victoria dam near Bickley to test the soundness of the aggregate and the bedrock at the foot of the wall. The crest of this dam was only four feet wide and large clamps were fabricated to hold the plant down on the wall and to provide access along each side of the drill.

The Fremantle Port Authority required some drilling done in Cockburn Sound in water up to fifty feet deep. A three legged tower in two sections of about 29 feet and 39 feet was constructed to our specifications. The top section of the tower has a drilling platform approximately 12 ft. x 12 ft. on which the rig was mounted. On the deck below close to water level the mud tank is placed. The tower was welded out of 8 in. bore casing and down two legs a line of N rod was run with an adjustable foot which can be raised or lowered from the drill platform to enable the operator to level the platform despite irregularities on the sea floor. The total weight of the tower together with drill and tanks is approximately 16 tons and to shift from site to site it was necesary to use the Harbour Trust floating crane. Copies of photographs of the tower published in *The West Australian* of June 11th, 1965 are attached.

Another innovation on this programme was the use of a salt water type drilling mud known as "Zeogel" which retains its properties when mixed with salt water. Experience has shown that where possible it is more efficient and economic to drill from a stable tower than from a floating platform subject to the vagaries of the weather and transport.

Five holes totalling 584 feet have been completed from the tower in this project.

Rig No. 8 (E500). This rig was on hire to various parties and Nil footage is recorded for the year.

Rig No. 9 (Gemco Auger). 1,797 feet were done by this machine at Yericoin, Arrino, Hopetoun, Pinjarra and Bunbury. The Bunbury job was continued from last year in the harbour. The drilling being done from a barge.

Rig No. 10 (Failing 750). This rig drilled 1,214 feet in eleven holes from a barge in Cockburn Sound on behalf of the Fremantle Port Authority. It was necessary to revert to a floating platform when it was found that the water in some instances was too deep to rig on the tower.

HYDROLOGICAL SECTION.

Rig No. 1 (Ruston-Bucyrus well drill) did 1,578 feet for the year. At Gnangara 1,298 feet in 12 holes were completed in a Water Resources survey. This plant was then transferred to Pinjarra where a hole 280 feet deep was in progress at the close of the period. Considerable trouble is being experienced at this site due to the presence of granite boulders in the hole at random elevations.

Rig No. 2 (Ruston well drill) completed 2,529 feet in 12 holes. One hole at Arrino for water was completed at 425 feet. Eleven holes were drilled at Gnangara in a Water Resources Survey for 2,104 feet.

GENERAL.

The policy of assistance to the drilling industry has been continued during the year and considerable quantities of equipment have been hired and loaned to various firms, and individuals and other Government Departments.

Enquiries as to most suitable equipment procedures and techniques are being constantly answered and advice given, involving considerable additional work to our staff above the usual duties of the depot.

Assistance in the way of plant, equipment, instruments or casing has been given to the undermentioned:—

Canadian Southern Cross Mines, Northampton.
Pickands Mather, Turkey Creek.
University of W.A., Exmouth.
Western Mining Corporation.
Darling Range Boring Coy.
Australian Blue Asbestos, Wittenoom.
Mount Goldsworthy Mining Associates.
Technical Drillers W.A.
P.W.D., Geraldton.
P.W.D., Derby.
P.W.D., Fremantle.
P.W.D., Capel.
P.W.D. Architectural Section.
Metropolitan Water Supply.
Geophysical Services International.
Foundation Engineering.
Raymond International.
F. K. Duffy.
Associated Diamond Drillers.
U.S. Metals Refining Coy., Port Hedland.
Westfield Minerals.
New Consolidated Goldfields.
Westphal Bros.
Great Southern Boring Coy.
Artesian Well Drilling Services.
Main Roads Department.
Seismic Supply Coy.
Hamersley Iron.
Electrolytic Zinc.
Shark Bay Salt.
J. O. Clough & Sons.
Swan Boring Coy.
Conzinc Rio Tinto.
K. Smith.
P. & L. Rond.
E. Scott.

Tabulated below are details of the drilling completed for the year.

J. HADDOW,
Inspector of Mines (Drilling).

17th March, 1966.

TABLE SHOWING FOOTAGE DRILLED FOR YEAR ENDED, 31st DECEMBER, 1965

Rig. No.	Machine	Place	Purpose	Footage	Total	Basis	Remarks
				ft. in			
2	Failing	Wanneroo	Water Supply	1,849 0			
		Bullsbrook	Water Supply	1,966 0			
		Moore River	Water Supply	1,556 0		Contract	
					5,371		
3	A. 3000	....	....	Nil	....	....	Hired.
4	A. 2000	South Dandalup....	Dam Foundation	395 6		Wages	4 holes.
					395½		
5	A. 2000	Mt. Gibson	....	....	....	....	Hired.
6	A. 2000	Morawa	....	....	....	....	Hired.
		Hopetoun	Water Supply	401 0		Wages	Air drilling 7 holes.
		Merredin	Quarry Site	208 6			6 holes.
		Turkey Creek	....	....			Hired.
					609½		
7	F. 20	Victoria Reservoir	Foundations	252 0		Wages	In concrete.
		Cockburn Sound	Foundations	584 0		Wages	5 holes.
					836		
8	E. 500	....	....	....	....	....	Hired.
9	Gemco	Yericoin	Water Supply	336 6		....	17 holes.
		Bunbury	Harbour Work	561 9		....	104 holes.
		Arrino	Water Supply	105 0		....	Cementing bore head.
		Hopetoun	Water Supply	732 0		....	28 holes.
		Pinjarra	Water Supply	62 0		....	Cementing borehead
					1,797		
10	Failing 750	Cockburn Sound	Harbour Work	1,214 0		....	11 holes.
					1,214		
			PERCUSSION RIGS				
1	R.B.22R.W.	Gnangara	Water Supply	1,298 0		....	6 holes.
		Pinjarra	Water Supply	280 0		....	In progress.
					1,578		
2	R.B.22R.W.	Arrino	Water Supply	425 0		....	1 hole.
		Gnangara	Water Supply	2,104 0		....	11 holes.
					2,529		
				TOTAL	14,330		

APPENDIX No. 2.

12th January, 1966.

The Chairman,
Board of Examiners for Mine Managers'
and Underground Supervisors' Certificates,
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 1965.

Mining Law Examination.

An examination in Mining Law for the Mine Managers' Certificate of Competency was held on 12th April, 1965.

Details were as follows:—

Entries	9
Admitted	9
Passed	8
Failed	1

The names of the successful candidates were:—

First Class.

E. J. Lea.
R. J. Lea.

Second Class.

G. Abatematteo.
C. R. Bird.
F. E. Byrnes.
F. Hodge.
H. A. Rymer.
J. J. Cappa.

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

Underground Supervisors Examination.

The written examination for the Underground Supervisors' Certificate of Competency was held on 7th Sepember, 1965 and applications were received from the following centres:—

Kalgoorlie	19
Mount Magnet	1
Geraldton	1
Wittenoom	8
Norseman .... (Subsequently withdrawn)	1
	30

Of the thirty (30) applications, twenty-nine were accepted, eight of these being accepted with the proviso that evidence of first aid and practical experience be submitted by 27th August, 1965. A total of twenty-four (24) candidates sat for the examination.

The results were as follows:—

Examined	24
Passed	18
Failed	6

Certificates of competency have been issued to the successful Candidates whose names are as follows:—

Brooks, Barry Edward—Kalgoorlie.
Burton, Eric Albert—Kalgoorlie.
Cavassi, Maurice John—Kalgoorlie.
Gledhill, Reginald Norman—Kalgoorlie.
Higgins, Kevin Arthur—Kalgoorlie.
Hobba, Ronald James—Kalgoorlie.
Jongen, Petrus Joseph Franciscus Gerardus —Kalgoorlie.
Kingswood, Jack Thomas—Kalgoorlie.

Lubbock, Frank Norman—Kalgoorlie.
O'Callaghan, Gerald Anthony—Mt. Ida.
Peters, Raymond William—Kalgoorlie.
Unkovich, Anthony—Kalgoorlie.
Varley, Clifford George—Kalgoorlie.
Virgin, Benjamin Trevor—Kalgoorlie.
Watson, Frederick George—Kalgoorlie.
Chapman, John Patrick—Wittenoom.
Lossie, Joseph Cornelius—Wittenoom. (Restricted to Asbestos mining only.)
Dodd, Leopold Edward—Wittenoom.

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

Mine Managers' Certificates.

One application for a Mine Managers' Certificate of Competency (old type) was approved to:—

Fraser, P. G. S.

Under the New Mines Regulation Act.

The following were successful applicants for Mine Managers' Certificates:—

First Class.

E. J. Lea.
I. R. Letts.

Second Class.

J. J. Cappa.
H. A. Rymer.

Two applications for First Class Certificates were refused, one on the grounds that the applicant had not complied with the regultaions as instructed and the other was advised to sit for the Mining Law examination in 1966 and re-submit his application after gaining a further twelve months experience in Metaliferous Mining Methods.

One application for a Second Class Certificate was refused on the grounds that the applicant did not possess the necessary qualifications.

General.

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

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

Kalgoorlie.
Mt. Ida.
Wittenoom.

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

Mines Regulation Act, 1946-61

Examination for Mine Manager's Certificate of Competency
1st Class

MINING LAW

April, 1965

Time Allowed—Three (3) hours

Attempt Seven (7) questions from Section A
Attempt Three (3) questions from Section B

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 must 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. (a) Electric firing.
   (b) Firing in winzes.
2. (a) Penthouses.
   (b) Construction of an underground dam.
3. (a) Men working alone.
   (b) Platman and braceman.
4. (a) Transport of explosives.
   (b) Burning rate of safety fuse.
5. (a) Times of blasting.
   (b) Recirculation of air.
6. (a) Signals to be used when firing adjacent to a shaft.
   (b) Clearing chutes and passes which have become 'hung up'.
7. (a) Ventilation officers.
   (b) Unconsciousness arising from the inhalation of fumes.
8. (a) Rises.
   (b) The placement of winzes, and the arrangements of pipes, valves, hoses and ladders during sinking operations.
9. (a) Safety provisions for underground locomotives.
   (b) Use of the English language in and about a mine.
10. Raising or lowering men or material in a cage, skip, kibble or similar appliance—give safety requirements.

SECTION B

(Mining Act and Regulations)

Attempt Three (3) questions from this section.

Do Not attempt more than Three (3) questions from this section.

Marks allowed are Ten (10) per question.

11. (a) What is private land?
    (b) What are the obligations of a lessee regarding exploratory bore holes drilled on his property?
12. (a) A lease may be declared void, cancelled, or forfeited. If this is done when is the land open for selection?
    (b) If a lease is surrendered what must the lessee do with regard to any tailings on the lease if he wishes to retain possession of the tailings?
13. (a) If exemption from labour conditions has not been granted, when must these conditions be complied with on—
        (i) A Gold Mining Lease.
        (ii) A Mineral Claim.
        (iii) A Mineral Lease.
    (b) Concentration of labour on Gold Mining Leases may be granted. How many men is it necessary to employ to comply with labour conditions?
14. (a) What is the term of a Gold Mining Lease?
    (b) State 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.
15. (a) What Crown Land cannot be granted as a Gold Mining Lease?
    (b) If a mining lease extends into a townsite, suburban area, or other reserve, what protection does the Act provide for those who have surface rights?

Mines Regulation Act, 1946-61

Examination for Mine Manager's Certificate of Competency
2nd Class

MINING LAW

April, 1965

Time Allowed—Three (3) hours

Attempt seven (7) questions from Section A
Attempt three (3) questions from Section B

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 must 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. (a) Electric firing.
   (b) Firing in winzes.
2. (a) Penthouses.
   (b) Construction of an underground dam.
3. (a) Men working alone.
   (b) Platmen and bracemen.
4. (a) Transport of explosives.
   (b) Burning rate of safety fuse.
5. (a) Times of blasting.
   (b) Recirculation of air.
6. (a) Signals to be used when firing adjacent to a shaft.
   (b) Clearing chutes and passes which have become "hung up".
7. (a) Ventilation officers.
   (b) Unconsciousness arising from the inhalation of fumes.
8. (a) Rises.
   (b) The placement of winzes, and the arrangements of pipes, valves, hoses and ladders during sinking operations.
9. (a) Safety provisions for underground locomotives.
   (b) Use of the English language in and about a mine.
10. Raising or lowering men or material in a cage, skip, kibble or similar appliance—give safety requirements.

SECTION B

(Mining Act and Regulations)

Attempt three (3) questions from this section

Do not attempt more than three (3) questions from this section

Marks allowed are ten (10) per question

11. (a) How long does a miner's right remain in force?
    (b) If the holder of a miner's right wishes to obtain a new miner's right effective from the expiration of the old one without payment of any fee other than the normal fee for a miner's right, what must he do?
    (c) What is necessary before any person can commence proceedings in a warden's court?
12. If exemption from labour conditions has not been granted when must these conditions be first complied with on—
    (a) A Gold Mining Lease.
    (b) A Mineral Lease.
    (c) A Prospecting Area.
13. (a) A miner wishes to mark off a Prospecting Area on private land. What must he first do?
    (b) What is the maximum area of such a Prospecting Area and for how long can it be held?
    (c) How do the area and term differ for those of a Prospecting Area on Crown land?
14. (a) How would you mark off a Gold Mining Lease?
    (b) When must application be made for a lease that has been marked off?
    (c) When must an objection be lodged against the granting of a lease?

Western Australia

Mines Regulation Act, 1946-61

Examination for Certificate of Competency as Underground Supervisor

MINING

September, 1965

Time Allowed Three (3) Hours
Attempt Six (6) Questions Only
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. Describe in detail, one method of stoping an orebody.

Explain under what circumstances you would use the method described and draw a sketch showing full details of the stope when it is advanced 50 feet from the level.

2. Explain in detail, how you would make an examination of a 3 compartment vertical working shaft, 1,000 feet deep.

—OR—

Explain in detail how you would make an examination of a working 3 compartment underlay shaft 1,000 feet deep.

—OR—

Explain in detail how you would make an examination of a main adit 2,000 feet long in which both underground locomotives and a conveyor belt are working.

3. A winze 100 feet deep has just been fired. Describe how you would clean out the broken rock and examine the bottom before boring the next face.

—OR—

A rise face has just been fired. The face is 60 feet above the back of the drive and the rise inclines at 60°. Describe what you would do before boring the next face.

4. (a) An ore pass which is vertical has become "hung up." Explain fully the procedure you would take to clear it.

(b) An opening used for drawing off ore from a shrinkage stope has become obstructed by large rocks. Explain fully the procedure you would take to clear it.

Note: Question 4 must be answered from the view of practical mining.

5. What safety precautions are essential in two of the following—

(a) operating a Mechanical Loader in a leading stope.

(b) operating an Underground locomotive on a working level when it is necessary to load ore from chinamen chutes, one of which is close to a "dead end".

(c) Driving a hoist scraping ore to an ore pass in a flat stope.

6. What ventilation and dust suppression precautions would you as Mine Supervisor, take to ensure maximum safety and healthy conditions for men working in a mine?

7. Write what you know about explosives usually used underground, the necessary precautions for safe handling, and how to charge a drive face.

8. Describe fully one method of shaft timbering in common use, stating how the timbers are placed in position. Give sketches.

—OR—

The hanging wall of a flat open stope has become weakened. It is necessary to keep the area open. How would you support the wall? Give sketches.

Western Australia

Mines Regulation Act, 1946-61

Examination for

Certificate of Competency as Underground Supervisor

MINING LAW

September, 1965

Time Allowed: Two (2) Hours

Attempt Twelve (12) Questions

Read the Examination Paper Carefully.

Answers must be written in ink.

What is required by the Mines Regulation Act or the Regulations made under that Act regarding any Twelve (12) of the following:—

1. Precautions to be taken when repairing shafts.
2. Use of safety belts.
3. Boring in butts.
4. A development end which is approaching a place likely to contain an accumulation of water.
5. How many fuses may be lit in shaft sinking.
6. What, if anything, is necessary before a rise can be commenced.
7. Gates to cages.
8. Times of blasting.
9. Clearing passes and chutes.
10. The burning rate of fuse.
11. The sinking signal.
12. The accident signal.
13. Change houses.
14. Ventilation in development ends.
15. Men working alone.
16. Safety provisions for Underground Locomotives.
17. Waste timber underground.
18. Method of obtaining a Hoist Driver's Certificate.

Index to State Mining Engineer's Annual Report for 1965

DIVISION III

Report of the Superintendent of State Batteries—1965

UNDER SECRETARY FOR MINES

For the information of the Hon. Minister for Mines, I submit my report on the operations of the State Batteries for the year ending 31st December, 1965.

Crushing Gold Ores.

One 20 head, five 10 head, and ten 5 head mills crushed 41,481 tons of ore made up of 369 separate parcels, an average of 110.29 tons per parcel. The bullion produced amounted to 14,937 ozs. which is estimated to contain 12,660 ozs. of fine gold, equal to 6 dwts. 3 grs. of gold per ton of ore.

The cost of crushing, including administration was 78/6 per ton, an increase of 7/11 per ton compared with the previous year when 43,966¾ tons were crushed at a cost of 70/7 per ton.

The average value of the ore after amalgamation, but before cyanidation was 2 dwts. 3 grs. Thus the average head value of the ore was 8 dwts. 6 grs. which is 10 grs. less than the previous year's average.

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

	Tons	%
Over 2 dwts. 8 grs. per ton	8,074¾	19·5
1 dwt. 18 grs. to 2 dwts. 8 grs. per ton	3,560	8·6
Under 1 dwt. 18 grs. per ton	29,835	71·9
Refractory	11¼	·0
	41,481	100·0

Cyaniding.

Eight plants treated 15,705 tons of tailings from amalgamation for a production of 2,467 fine ozs. of gold worth £38,597. The average content was 4 dwts. 6 grs, before cyanidation, while the residue after treatment averaged 1 dwt. 1 gr. The theoretical extraction was, therefore, 75%. The actual extraction was 74%.

The cost of cyaniding was 59/4 per ton, an increase of 3/8 per ton on the previous year, when 19,709 tons were treated at a cost of 55/8 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	17,081	8	6	100·0
Amalgamation Recovery	12,660	6	3	74·2
Cyanidation Recovery	2,467	1	4	14·1
Total Recovery	15,127	7	7	88·3

Treatment of Ores Other than Gold.

Lead Ores.

During the year the Northampton State Battery crushed 7,231¾ tons of lead ore with an estimated average content of 11.96% lead. There were 34 separate parcels, giving an average of 213 tons of ore per parcel.

A total of 1,016.78 tons of concentrates was produced. The concentrates averaged 72.22% lead, giving an estimated content of 734.32 tons of lead in concentrates.

6,125 tons of tailings were discarded. These had an average content of 2.11% lead, giving a total of 130.77 tons of lead discarded in tailings.

The recovery of lead in the concentrates was 84.9% of the lead in the ore delivered to the plant.

The cost of operating the Northampton State Battery, including administration, was £18,514.1.2, being 51/3 per ton of ore crushed. Revenue received was £7,625.15.0 being 20/1 per ton. The corresponding figures for 1964 when 2,925¼ tons of ore were crushed, were operating cost £10,067.3.7, 68/10 per ton, and revenue £2,544.9.0, 17/5 per ton.

Sales of lead concentrates from the Northampton State Battery for the year were valued at £84,850.

Tin Ore— The Marble Bar Battery crushed 122 tons of ore for 6 cwt. of concentrates and the Norseman Battery 325 tons for 3 tons 4 cwt. of concentrates. Total value of these concentrates was £3,625.

Tantalite Ore— No treatment for the year.

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

	1965 £	Grand Total £
Par Production—		
Crushing	53,775	8,919,011
Cyanidation	10,516	2,194,131
Gold Premium—		
Crushing	144,033	5,791,525
Cyanidation	28,080	1,600,948
Open Market Premium—		
Crushing	1,061	33,786
Cyanidation	207	10,962
Total Gold Production	£237,672	£18,550,363

OTHER ORE REALISED

	1965 £	Grand Total £
Tin—		
Ores	3,625	97,966
Residues	*Nil*	572
Tungsten Concentrates	*Nil*	18,850
Agricultural Copper Ore	*Nil*	5,966
Lead Concentrates	84,850	447,835
Tantalite Concentrates	*Nil*	12,950
Total Other Ores	£88,475	£584,139
Grand Total	£326,147	£19,134,502

FINANCIAL

	Tons	Expenditure	Receipts	Loss
		£	£	£
Crushing (Gold Mills	41,928	164,609	17,449	147,160
Crushing (Northampton)	7,231¾	18,514	7,626	10,888
Cyaniding	15,705	46,606	15,280	31,326
	....	£229,729	£40,355	£189,374

The loss of £189,374 is an increase of £8,803 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.
Coolgardie	Cyanide Plant	8,002 19 7
Cue	Cyanide Plant	91 5 7
Lake Darlot	Cyanide Plant	861 1 9
Meekatharra	Water Supply	292 19 7
Ora Banda	Cyanide Plant and Crude Ore Bins	*14 11 5
Portable Welder ..	....	353 8 4
Front End Loader	....	1,673 6 8
		£11,260 10 1

* Credit.

Cartage Subsidies	Tons	Cost
Ore carted to State Plants	10,134	£5,894

Comparative figures for the last three years are:

Year	State Plants				Private Plants		
	Tons Crushed	Tons Subsidised	Per-cent. Subsidised	Cost	Tons Subsidised	Cost	Total Cost
				£		£	£
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
1965	49,159¾	10,134	20·6	5,894	*Nil*	*Nil*	5,894

Administrative.

Expenditure amounted to £28,341.15.5 equivalent to 8/9 per ton of ore crushed and cyanided, compared with an expenditure of £28,662.5.7, 8/7 per ton, for 1964.

	1964 £ s. d.	1965 £ s. d.
Salaries	18,408 6 10	17,595 8 3
Pay Roll Tax	3,517 13 8	3,763 4 7
Workers' Compensation	3,506 1 10	3,598 14 4
Travelling and Inspection	1,870 11 8	2,427 8 3
Sundries	1,359 11 7	957 0 0
	£28,662 5 7	£28,341 15 5

Staff.

F. C. Turner was appointed Manager of the Menzies Battery.

Manager McPherson was transferred from Yarri to Meekatharra.

Manager Thompson was transferred from Meekatharra to Norseman.

General.

The tonnage of gold ore crushed was a little lower than in 1964. The average head value of the ore was lower, but because of some very rich crushings, the recovery by amalgamation was more than the previous year.

Cyanide plants treated 4,005 tons less than in 1964. This was due to the slow delivery of two scraper haulers which were ordered for delivery in July but had not been recieved by the end of the year.

As expected, the Northampton Battery was kept busy for most of the year, crushing considerably more than double the amount of lead ore crushed in 1964. This caused a reduction of 17/7 in the crushing costs per ton. Providing the price of lead remains over £100 Sterling per ton, the Northampton Battery should continue crushing at a high rate.

A total of 447 tons of tin ore was crushed, 122 tons at Marble Bar and 325 tons at Norseman. The value of the tin concentrates produced at Norseman was £3,340, giving an average return of over £10 per ton of ore crushed. Development work during 1966 should give some idea of the size of the Norseman tin ore deposits.

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, 1965.

Battery	Tons Crushed	Gold Yield Bullion	Value per Ton in Shillings	Total Value without Premium
		oz.		£
Boogardie	160·50	62·50	28·03	225·00
Coolgardie	3,641·25	3,803·45	75·21	13,692·42
Cue	586·75	195·80	24·03	704·88
Kalgoorlie	7,892·25	3,539·55	32·29	12,742·38
Lake Darlot	2,769·00	1,460·90	37·99	5,259·24
Leonora	322·00	92·60	20·71	333·36
Marble Bar	886·75	471·95	38·32	1,699·02
Marvel Loch	2,249·75	1,061·95	33·99	3,823·02
Meekatharra	2,906·25	978·25	24·24	3,521·70
Menzies	3,446·25	566·50	11·84	2,039·40
Norseman	97·00	66·20	49·14	238·32
Nullagine	68·00	10·30	10·91	37·08
Ora Banda	14,627·00	2,244·25	11·05	8,079·30
Peak Hill	1,304·00	100·05	5·52	360·18
Sandstone	145·25	74·85	37·10	269·46
Yarri	379·00	208·35	39·58	750·06
Total	41,481·00	14,937·45	25·93	53,774·82

SCHEDULE No. 2.

Number of Parcels Treated, Tons Crushed and Head Value for the year ended 31st December, 1965.

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.
2	Boogardie	160·50	62 10	52 19	11 14	64 13	8 1	1 14 2
62	Coolgardie	3,641·25	3,803 9	3,223 8	591 15	3,815 3	20 23	4 9 0
6	Cue	586·75	195 16	165 19	215 0	380 19	13 0	2 15 3
91	Kalgoorlie	7,892·25	3,539 11	2,999 15	705 17	3,705 12	9 9	1 19 10
26	Lake Darlot	2,769·00	1,460 18	1,238 2	517 5	1,755 7	12 16	2 13 10
5	Leonora	322·00	92 12	78 10	33 13	112 3	6 23	1 9 7
24	Marble Bar	886·75	471 19	400 0	104 2	504 2	 11	1 11
31	Marvel Loch	2,249·75	1,061 19	900 0	362 7	1,262 7	11 5	2 7 7
16	Meekatharra	2,906·25	978 5	829 1	304 3	1,133 4	7 19	1 13 1
43	Menzies	3,446·25	566 10	480 2	281 7	761 9	4 10	18 9
11	Norseman	97·00	66 4	56 2	15 13	71 15	14 19	3 2 10
3	Nullagine	68·00	10 6	8 15	 16	9 11	2 19	11 10
42	Ora Banda	14,627·00	2,244 5	1,902	1,166 13	3,068 13	4 5	17 10
5	Peak Hill	1,304·00	100 1	84 16	56 6	140 22	2 4	9 3
3	Sandstone	145·25	74 17	63 9	26 15	90 4	12 10	2 12 9
7	Yarri	379·00	208 7	176 12	27 18	204 10	10 19	2 5 10
377		41,481·00	14,937 9	12,659 10	4,421 4	17,080 14	8 6	1 15 1

Average Tons per Parcel .... 110·03
Average Yield by Amalgamation per ton (Fine Gold) .... 6 dwts. 3 grs.
Average Head Value of Tailings per ton (Fine Gold) .... 2 dwts. 3 grs.

Schedule No. 3.

Segregation of Tailings Produced According to Value, year ended 31st December, 1965.

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	15·75	3	17	....	....	....	144·75	7	17	....	....	....	160·50	11	14
Coolgardie	1,117·75	443	4	400·75	40	18	2,111·50	104	7	11·25	3	6	3,641·25	591	15
Cue	586·75	215	....	....	....	....	....	....	....	....	....	....	586·75	215	....
Kalgoorlie	1,980·00	421	10	1,048·00	78	17	4,864·25	205	10	....	....	....	7,892·25	705	17
Lake Darlot	1,712·50	443	11	192·00	13	7	864·50	60	7	....	....	....	2,769·00	517	5
Leonora	238·00	31	13	....	....	....	84·00	2	....	....	....	....	322·00	33	13
Marble Bar	230·75	81	2	52·25	5	9	603·75	17	11	....	....	....	886·75	104	2
Marvel Loch	589·00	263	9	262·50	28	2	1,398·25	70	16	....	....	....	2,249·75	362	7
Meekatharra	449·75	140	15	55·00	5	19	2,401·50	157	9	....	....	....	2,906·25	304	3
Menzies	335·00	71	13	806·50	63	18	2,304·75	145	16	....	....	....	3,446·25	281	7
Norseman	34·00	8	19	63·00	6	14	....	....	....	....	....	....	97·00	15	13
Nullagine	....	....	....	....	....	....	68·00	....	16	....	....	....	68·00	....	16
Ora Banda	597·25	406	18	605·00	68	1	13,424·75	691	14	....	....	....	14,627·00	1,166	13
Peak Hill	....	....	....	75·00	7	19	1,229·00	48	7	....	....	....	1,304·00	56	6
Sandstone	145·25	26	15	....	....	....	....	....	....	....	....	....	145·25	26	15
Yarri	43·00	6	15	....	....	....	336·00	21	3	....	....	....	379·00	27	18
Total Gold	8,074·75	2,565	1	3,560·00	319	4	29,835·00	1,533	13	11·25	3	6	41,481·00	4,421	4

SCHEDULE No. 4.

Details of Extraction Tailings Treatment, 1965.

Battery	Tons Treated	Head Value		Contents	Tail Value		Contents	Re-covery	Call	Recovery	Shortage	Surplus
		dwts.	grs.	dwts.	dwts.	grs.	dwts.	%	£ s. d.	£ s. d.	£ s. d.	£ s. d.
Kalgoorlie	5,100	3	22	20,088	....	23	4,947	75	3,194 11 3	3,192 16 4	1 14 11	....
Marble Bar	180	11	5	2,017	2	19	496	75	323 1 1	327 15 5	....	4 14 4
Marvel Loch	2,835	4	18	13,628	1	16	3,300	76	2,193 11 4	2,200 3 7	....	6 12 3
Meekatharra	2,750	3	9	9,293	....	22	2,620	72	1,417 9 2	1,375 19 6	41 9 8	....
Norseman	1,920	2	22	5,594	....	18	1,431	74	884 5 2	870 12 10	13 12 4	....
Ora Banda	2,920	5	11	16,025	1	8	3,963	75	2,562 0 5	2,548 19 3	13 1 2	....
Total	15,705	4	6	66,645	1	2	16,757	75	10,574 18 5	10,516 6 11	69 18 1	11 6 7

Net Shortage	£58 11s. 6d.
Head Value	4 dwts. 6 grs.
Tail Value	1 dwt. 2 grs.
Theoretical Recovery	75 per cent.
Actual Recovery	74 per cent.

SCHEDULE No. 5.

Direct Purchase of Tailings.
Year ended 31st December, 1965.

Battery	Tons of Tailings Purchased	Amount Paid at £4 4s. 11½d. per oz.	Amount Paid Account of Premium
		£ s. d.	£ s. d.
Boogardie	139·25	49 0 1	112 10 0
Coolgardie	1,047·75	807 8 6	1,875 8 4
Cue	947·00	877 9 8	2,014 8 8
Kalgoorlie	2,222·00	591 12 11	1,833 0 3
Lake Darlot	1,552·00	666 16 4	1,530 16 3
Leonora	365·50	62 12 3	143 14 11
Marble Bar	105·75	317 17 6	831 9 3
Marvel Loch	481·75	549 18 11	1,676 0 0
Meekatharra	561·75	255 5 6	979 15 7
Menzies	356·75	111 15 6	256 11 11
Norseman	42·25	11 15 5	256 1 7
Ora Banda	590·00	1,063 3 7	2,950 6 9
Yarri	38·75	4 17 9	11 4 5
Total	8,450·50	5,369 13 11	14,471 7 11

SCHEDULE No. 6.

Cyanide Yield, 1965.

Battery	Tons	Fine oz.	Value	Premium	Total
			£	£	£
Kalgoorlie	5,100	745·96	3,192·816	8,487·788	11,680·604
Marble Bar	180	76·62	327·771	871·679	1,199·450
Marvel Loch	2,835	515·90	2,200·180	5,876·090	8,076·270
Meekatharra	2,750	323·92	1,375·974	3,685·454	5,061·428
Norseman	1,920	204·97	870·642	2,331·958	3,202·600
Ora Banda	2,920	599·96	2,548·962	6,827·249	9,376·211
Total	15,705	2,467·33	10,516·345	28,080·218	38,596·563

(4)—25843

SCHEDULE No. 7.

Statement of Receipts and Expenditure for the year ended 31st December, 1965.

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	160½	415 0 5	651 2 10	241 10 3	1,307 13 6	163 0	179 6 1	322 16 0	1,809 15 7	225 6	105 8 4	13 2	....	1,704 7 3
Coolgardie	3,641¼	3,518 9 2	7,169 1 5	2,146 10 4	12,834 0 11	70 6	4,046 10 10	2,733 14 4	19,614 6 1	107 4	1,656 9 3	9 1	....	17,957 16 10
Cue	586¾	2,961 10 3	941 12 1	677 10 7	4,580 12 11	156 1	1,752 4 6	672 13 8	7,005 11 1	238 9	322 19 2	11 0	....	6,682 11 11
Kalgoorlie	7,892¼	5,044 6 11	6,237 5 7	5,620 15 3	16,902 7 9	42 10	8,243 17 0	4,291 15 2	29,437 19 11	74 7	3,840 14 5	9 9	....	25,597 5 6
Lake Darlot....	2,769	3,928 7 2	4,070 1 1	1,462 4 8	9,460 12 11	68 4	1,735 8 6	1,823 3 8	13,021 5 1	94 0	1,357 6 4	10 9	....	11,663 18 9
Laverton	....	....	186 0 0	193 10 10	379 10 10	....	335 18 11	54 6 9	769 16 6	....	48 9 6	....	....	721 7 0
Leonora	322	589 11 1	822 7 0	431 10 5	1,843 8 6	114 6	769 12 5	494 14 8	3,107 15 7	193 0	195 8 6	12 1	....	2,912 7 1
Marble Bar	1,008¾	5,054 17 7	3,924 4 7	1,717 18 10	10,697 1 0	212 1	4,591 13 8	1,389 16 4	16,678 11 0	330 6	748 0 7	14 10	....	15,930 10 5
Marvel Loch	2,249¾	1,907 19 7	4,130 8 5	1,345 4 2	7,383 12 2	65 8	1,008 1 9	1,171 19 8	9,562 13 7	85 0	1,251 12 7	11 1	....	8,311 1 0
Meekatharra....	2,906¼	1,655 7 10	3,322 12 3	1,607 6 5	6,585 6 6	45 4	1,242 5 0	1,726 9 10	9,554 1 4	65 9	1,287 15 4	7 10	....	8,266 6 0
Menzies	3,446¼	1,878 16 10	4,849 3 0	1,302 7 0	8,030 6 10	44 10	644 7 11	2,137 2 2	10,811 16 11	62 9	1,411 6 8	8 2	....	9,400 10 3
Norseman	422	1,156 7 10	1,153 8 3	480 12 3	2,790 8 4	132 3	1,592 18 2	851 7 9	5,234 14 3	248 1	397 12 9	18 10	....	4,837 1 6
Nullagine	68	465 14 1	555 11 5	173 18 5	1,195 3 11	343 11	301 4 9	236 13 7	1,733 2 3	509 9	36 9 4	11 7	....	1,696 12 11
Ora Banda	14,627	2,892 6 10	7,798 16 1	4,092 4 11	14,783 7 10	20 3	4,760 1 2	6,561 14 5	26,105 3 5	35 8	4,015 16 10	5 6	....	22,089 6 7
Paynes Find	....	....	78 0 0	4 16 10	82 16 10	....	39 10 10	12 9 9	134 17 5	....	....	....	....	134 17 5
Peak Hill	1,304	843 12 10	1,934 12 10	406 11 2	3,184 16 10	48 10	587 16 10	994 19 9	4,767 13 5	75 1	449 15 0	6 11	....	4,317 18 5
Sandstone	145¼	383 3 2	353 2 4	79 12 0	815 17 6	112 4	35 3 7	238 3 10	1,089 4 11	150 0	63 11 7	8 9	....	1,025 13 4
Yarri	379	755 15 2	1,160 19 0	625 19 11	2,542 14 1	134 2	1,096 13 4	531 2 8	4,170 10 1	220 1	243 11 6	12 10	....	3,926 18 7
Head office	....	....	....	....	....	....	....	....	....	....	16 19 9	....	16 19 9	....
Sub-Total	41,928	33,451 6 9	49,338 8 2	22,610 4 3	105,399 19 2	50 6	32,963 15 3	26,245 4 0	164,608 18 5	78 6	17,449 7 5	8 4	16 19 9	147,176 10 9
Northampton	7,231¾	3,987 18 6	4,573 10 8	2,538 14 3	11,100 3 5	30 8	3,719 5 2	3,694 12 7	18,514 1 2	51 3	7,625 15 0	20 1	....	10,888 6 2
Total	49,159¾	37,439 5 3	53,911 18 10	25,148 18 6	116,500 2 7	47 5	36,683 0 5	29,939 16 7	183,122 19 7	74 6	25,075 2 5	10 3	16 19 9	158,064 16 11

NETT LOSS: £158,047 17 2

SCHEDULE No. 8.

Receipts and Expenditure, 1965.

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.
Kalgoorlie	5,100	2,119 3 4	4,225 2 10	3,690 9 5	10,034 15 7	39 6	643 0 6	2,855 10 1	13,533 6 2	53 1	6,368 17 5	12 8	....	7,164 8 9
Marble Bar	180	264 6 3	348 8 3	116 4 11	728 19 5	81 0	....	110 3 7	839 3 0	93 3	217 7 5	24 2	....	621 15 7
Marvel Loch	2,835	1,883 13 3	2,076 9 0	1,334 3 9	5,294 6 0	37 4	8 5 6	1,683 7 11	6,985 19 5	49 3	4,529 0 10	32 0	....	2,456 18 7
Meekatharra....	2,750	316 16 2	4,309 17 8	3,071 19 7	7,698 13 5	56 0	733 1 2	1,802 15 2	10,234 9 9	74 5	1,415 10 1	10 3	....	8,818 19 8
Norseman	1,920	1,023 6 4	1,726 10 7	838 16 4	3,588 13 3	37 4	256 0 1	1,500 19 3	5,345 12 7	55 8	1,507 12 1	15 8	....	3,838 0 6
Ora Banda	2,920	1,037 2 3	2,228 14 1	3,452 5 9	6,718 2 1	46 0	1,032 13 1	1,917 5 2	9,668 0 4	66 2	3,401 13 9	23 3	....	6,266 6 7
Total	15,705	6,644 7 7	14,915 2 5	12,503 19 9	34,063 9 9	43 4	2,673 0 4	9,870 1 2	46,606 11 3	59 4	17,440 1 7	22 3	....	29,166 9 8

Total Receipts	17,440 1 7		
Interest Paid to Treasury	2,160 0 0		£2,160 0 0
	15,280 1 7	Gross Loss	£31,326 9 8

STATE BATTERIES.

Trading and Profit Loss Account.

For the year ended 31st December, 1965.

1964 £		1965 £	
	Trading Costs—		
112,188	Wages	112,911	
37,955	Stores	37,653	
30,364	Repairs, Renewals and Battery Spares	39,356	
40,057	General Expenses and Administration	41,969	
220,564			231,889
	Earnings—		
39,993	Milling and Cyaniding Charges		42,515
180,571	Operating Loss for the Year		189,374
	Other Charges—		
27,436	Interest on Capital	27,943	
15,155	Depreciation	13,762	
2,731	Superannuation—Employers Share	2,918	
45,322			44,623
£225,893	Total Loss for the Year		£233,997

STATE BATTERIES.

Balance Sheet.

As at 31st December, 1965.

31st December, 1964 £	Funds Employed	31st December, 1965 £	£
	Capital—		
657,693	Provided from General Loan Fund	669,053	
137,204	Provided from Consolidated Revenue Fund	137,204	
794,897			806,257
	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—		
1,078,767	Interest on Capital		1,106,709
15,000	Advance for Purchase of Tailings		15,000
	Other Funds—		
2,057,821	Provided from Consolidated Revenue Fund (Excess of payment over collections)		2,252,210
3,988,893			4,222,584
	Deduct—		
	Profit and Loss :		
3,537,183	Loss at Commencement of year	3,763,076	
225,893	Loss for Year	233,997	
3,763,076	Total Loss from Inception		3,997,073
£225,817			£225,511
	Employment of Funds		
	Fixed Assets—		
789,306	Plant, Buildings and Equipment	800,666	
670,842	*Less* Depreciation	684,603	
118,464			116,063
	Current Assets—		
2,528	Debtors	3,787	
85,009	Stores	87,647	
4,053	Battery Spares	4,057	
	Purchase of Tailings :		
3,113	Treasury Trust Account	3,882	
64,351	Tailings not treated	60,826	
8,535	Estimated Gold Premium	8,332	
167,589			168,531
286,053	Total Assets		284,594
	Deduct—		
	Current Liabilities :		
9,464	Creditors	8,351	
37,773	Liability to Treasurer (Superannuation—Employers Share)	40,692	
	Purchase of Tailings :		
4,464	Creditors	1,708	
8,535	Estimated Premium Due	8,332	
60,236			59,083
£225,817			£225,511

DIVISION IV

Annual Report of the Geological Survey Branch of the Mines Department for the Year 1965

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LIST OF FIGURES

DIVISION IV

Annual Report of the Geological Survey Branch of the Mines Department for the Year 1965

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 1965, together with some reports on investigations made for departmental purposes.

ORGANIZATION

Chiefly because of the boom in exploratory work and the shortage of experienced geologists in Australia, there were several resignations of professional staff during the year and difficulty was experienced in filling newly created positions.

The most serious loss was through the resignation of the Deputy Director, Mr. N. J. Mackay, who had given valuable service in the reorganization of the Survey during the past 3½ years. Other geologists who resigned have also made noteworthy contributions.

Four new positions were created in the Hydrology Division as a result of financial assistance being provided by the Commonwealth Government for groundwater research. Only two of these have been filled and recommendations have been made for appointments to the remaining positions.

The Sedimentary (Oil) Division has difficulty in keeping abreast of the current expanded programme of exploration being undertaken by companies. Recommendations for an increase in staff for this Division are still under consideration.

Efforts to recruit an additional geophysicist have also been unsuccessful.

APPOINTMENTS

Professional:

Name	Position	Effective Date
R. A. Farbridge, B.Sc. (Hons.)	Geologist, Grade 2	5/1/65
B. S. Ingram, B.Sc. (Hons.)	Geologist, Grade 2	16/2/65
C. C. Sanders, B.Sc. (Hons.)	Geologist, Grade 2	22/2/65
D. H. Probert, B.Sc.	Geologist, Grade 1	9/3/65
J. G. Blockley, B.Sc. (Hons.)	Geologist, Grade 2	12/4/65
T. T. Bestow, B.Sc. (Hons.)	Senior Geologist	28/12/65

Clerical and General:

J. R. Sorensen	Laboratory Assistant	5/1/65
K. A. Gayski	Laboratory Assistant	5/1/65
R. A. Taylor	Geological Assistant	17/5/65
M. S. Quigley	Geological Assistant	24/5/65
P. J. Bryant	Laboratory Assistant	18/10/65

Promotions:

W. N. MacLeod	Supervising Geologist to Deputy Director	19/8/65

Resignations:

H. S. Edgell	Palaeontologist	15/5/65
N. J. Mackay	Deputy Director	2/7/65
P. J. Jefferies	Laboratory Assistant	22/7/65
R. Halligan	Geologist, Grade 2	22/10/65
G. R. Ryan	Geologist, Grade 1	17/12/65

ACCOMMODATION

The upper floor of a warehouse was converted to provide additional office accommodation for the Geological Survey during this year. The Branch now occupies five separate small buildings in three adjoining streets. This is unsatisfactory from all viewpoints and there is overcrowding in the library and records section.

As a result of representations, a detailed investigation has been made of the office requirements and it is hoped that some action will be taken shortly to improve the situation.

The proposed expansion of the Government Records Repository at Dianella may necessitate a rearrangement or eventual replacement of the camp equipment store. Additional storage space will be required by the core library during the next financial year.

OPERATIONS

HYDROLOGY AND ENGINEERING GEOLOGY DIVISION

E. P. D. O'Driscoll (Chief Hydrogeologist), K. Berliat, F. R. Gordon, T. T. Bestow, J. D. Wyatt, D. H. Probert, A. D. Allen, E. E. Swarbrick, P. Whincup, R. A. Farbridge, C. C. Sanders, R. Milbourne, and J. R. Passmore (on leave without pay while engaged on a Water Foundation research project).

Hydrology

Exploratory drilling in the Arrowsmith River area near Arrino continued and twelve exploratory bores were completed. The Mandurah project continued, but only four holes were completed because of the very slow rate of drilling by the contractor.

The investigation of the Gnangara Lake area has been extended northwards with the completion of 18 more exploratory bores. Four bores were completed in the long-term programme of deep drilling the Perth Basin.

Drilling programmes are in progress as a result of field surveys at Albany and Port Hedland. A similar project has been completed at Esperance and a regional geological and groundwater survey of the Esperance region has been commenced.

Drilling programmes were recommended and completed for Hopetoun, Moora, Yerecoin, Mt. Magnet and Meekatharra townships. Geological advice was supplied on the town water supply prospects at Coomberdale, Ravensthorpe, Dunsborough-Quindalup, Boyanup, Guilderton, Donnybrook, Capel and Horrocks Beach.

The groundwater resources of a portion of the Kimberley Area were assessed concurrently with the regional mapping programme. The Division continued to provide an advisory service to landholders, companies and other government departments.

The service provided by contractor drillers has deteriorated, resulting in long delays in the programmes, and in some cases the standard of the results has been poor.

Engineering Geology

A detailed investigation of the barrage site at Gogo on the Fitzroy River was initiated and reconnaissance surveys were made of some of the prospective sites on tributaries at Barramundi Range, Mt. Krauss and at Macdonald Gorge on the Margaret River.

The valley where the Gascoyne River flows through the Kennedy Range was selected as a possible dam site and a detailed investigation was commenced.

Detailed investigation of dam sites on the Darling Scarp south of Perth was continued. Work on the Wungong Brook dam sites was completed and work on the South Dandalup River is in progress. Work was done also on the following proposed and existing dams: Harvey, Moochalabra Creek near Wyndham, Mundays Brook and Serpentine.

The stability and maintenance of the cuttings on the Avon Valley Deviation of the Standard Gauge Railway were appraised and recommendations were made. Ballast materials between Toodyay and Kalgoorlie were investigated.

SEDIMENTARY (OIL) DIVISION

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

An increasingly large part of the Division's time was occupied in appraising the results of oil exploration in Western Australia and in administrative matters relating to this exploration. Company activities continued to expand in all the major sedimentary basins, and further discoveries were made at Barrow Island (oil and gas) and Gingin (gas).

A bulletin (No. 118) on the Devonian reef complexes was completed.

The detailed mapping of the Perth Basin continued and a report was prepared on the southern part of this basin.

Systematic geological mapping of the Eucla Basin was commenced during the year and will be continued during 1966. Brief field trips were made to the Canning and Bonaparte Gulf Basins.

REGIONAL GEOLOGY DIVISION

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

Eastern Goldfields Area

Field work was completed on the Kalgoorlie 1:250,000 Sheet and mapping of the Kurnalpi 1:250,000 Sheet was commenced. Information and reports were supplied to local pastoralists and prospectors on hydrology and geology.

Pilbara Area

Field work was completed on the Edmund 1:250,000 Sheet. Information was supplied to pastoralists on groundwater problems and to mining companies on regional geology. Advice was given to prospectors on mineralization.

Kimberley Area

Geological mapping, in conjunction with the Bureau of Mineral Resources, was completed on the Londonderry, Drysdale, Ashton, Mt. Elizabeth, Montague Sound, Prince Regent and Camden Sound 1:250,000 Sheets. Work was commenced on the Charnley and Lennard River 1:250,000 Sheets.

One geologist was engaged on the preparation of a bulletin on the East Kimberley area.

General

A new geological map of this State has been compiled by collating all geological work, by producing photogeological maps for some areas that are not mapped, and by reconnaissance geological traverses through some parts of the State.

Samples were selected for a joint programme of rock age-determinations with members of the Australian National University, in Canberra. Field trips were made with visiting geologists and members of the Commonwealth Scientific and Industrial Research Organization.

The progress of geological mapping at 1:250,000 scale during the past 5 years is shown on Figs. 1 and 2.

MINERAL RESOURCES DIVISION

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

The comprehensive survey of the blue asbestos deposits of the Hamersley Range area was continued throughout the year with two geologists fully engaged on the project. Field work for this investigation will be continued and should be completed in 1966.

One geologist of the Division was attached to the joint regional mapping party in the Kimberley Division in an appraisal of the mineral potential of the northern part of the Kimberley Plateau. Newly discovered bauxite deposits in this region were examined and reported upon.

Regional mapping and examination of the mineral potential of the Robertson 1:250,000 Sheet was completed during the year.

In the later part of the year the Koolyanobbing "A" deposit of iron ore was mapped and drilled, and ore reserves were evaluated on behalf of the Wundowie Charcoal Iron and Steel Industry.

A survey of the pegmatite mineralization in the Yalgoo and Murchison Goldfields was commenced late in the year. All known productive centres were visited and several areas were selected for more detailed mapping as the investigation proceeds.

Other investigations included an examination of the ilmenite-bearing sands at Lake Boondanoo in the Yalgoo goldfield; sampling of the manganiferous iron ore at Mt. Caudan in the Yilgarn Goldfield; and examinations of a copper prospect near Nullagine and a gold prospect near Mt. Magnet.

COMMON SERVICES DIVISION

Petrology (A. F. Trendall)

Twenty file reports were written, involving 432 rocks from many parts of the State. This material was received from all Divisions of the Geological Survey, from other Government organizations, and from the public. Geologists carrying out petrological work on their own rock collections were advised and assisted. A total of 1,244 thin sections and 47 polished mounts were prepared in the laboratory, and photomicrography was carried out for record and publication purposes.

One month was spent in the field, accompanying a Research Fellow of the Australian National University during collection of specimens for isotope geochronology in the Pilbara area, and later carrying out detailed field work in support of the blue asbestos investigation.

It is increasingly apparent that the Brockman Iron Formation of the Hamersley area is the best formation in the world in which to look for evidence of the origin and geological significance of this economically important rock type, and work on it has occupied much of the Petrologist's time. The Geological Survey follows a policy of encouraging outside organizations to join in co-operative or supplementary contributions to such specific studies, especially laboratories using expensive and specialised techniques, and such laboratories working on material from the Brockman Iron Formation included several overseas and eastern Australian institutions. It is convenient for the Petrologist to co-ordinate the progress of this work.

Chemical and physical (X-ray) support for many petrological studies was given, as in previous years, by staff of the Government Chemical Laboratories.

Palaeontology (H. S. Edgell—resigned 11/5/65, and B. S. Ingram)

Early in the year a junior palynologist was recruited to work under Dr. Edgell. Unfortunately the latter resigned shortly afterwards. Mr. B. E. Balme, of the University of Western Australia supervised palynology for the remainder of the year. His assistance is gratefully acknowledged.

During the year over 100 samples were submitted for palaeontological examination chiefly by the Hydrology Division. Thirty four file reports on the results were prepared.

GEOLOGICAL SURVEY OF WESTERN AUSTRALIA

1 : 250,000 OR 4 MILE GEOLOGICAL MAPPING

1960

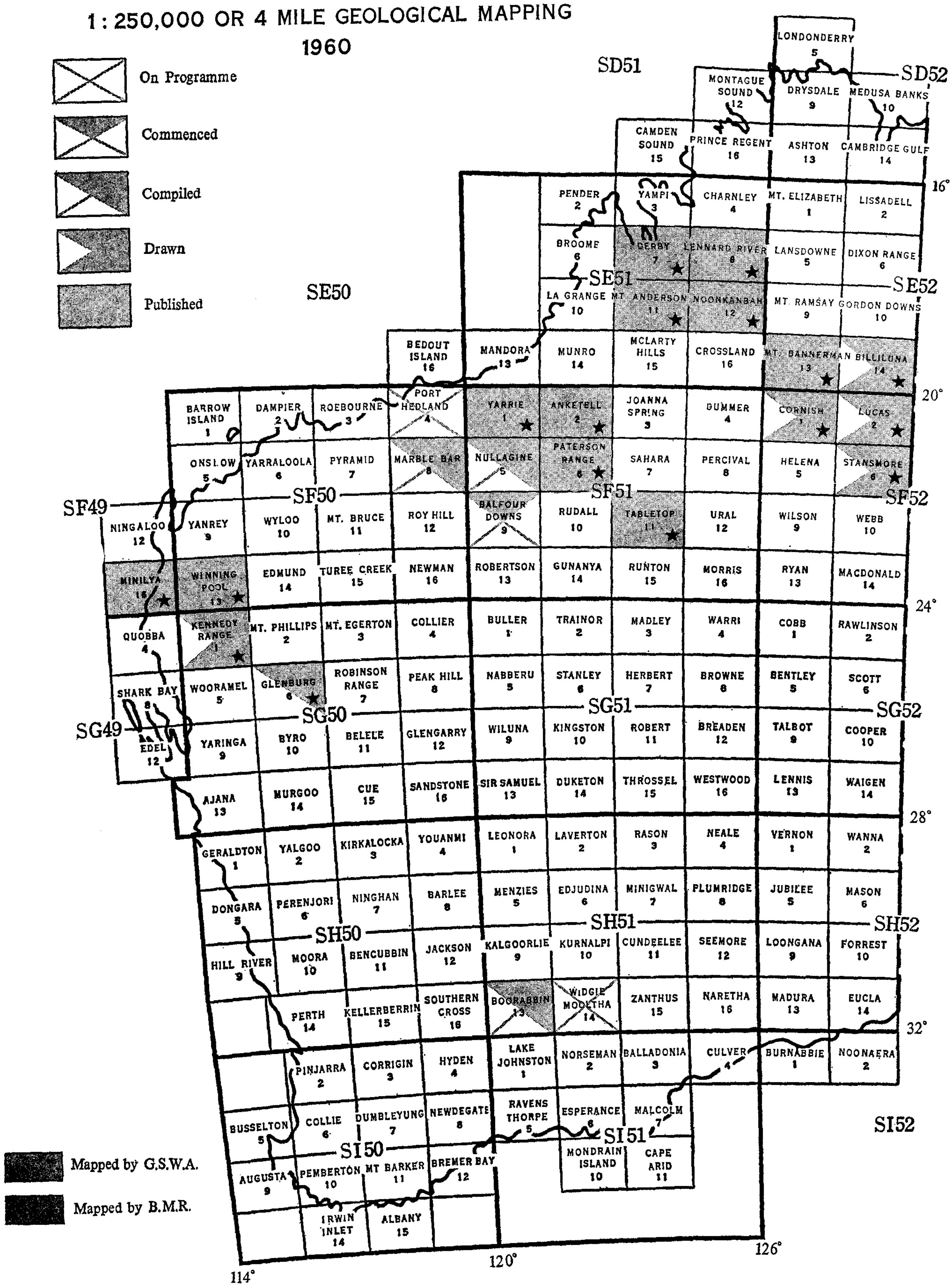

FIGURE 1

GEOLOGICAL SURVEY OF WESTERN AUSTRALIA

1:250,000 OR 4 MILE GEOLOGICAL MAPPING

1965

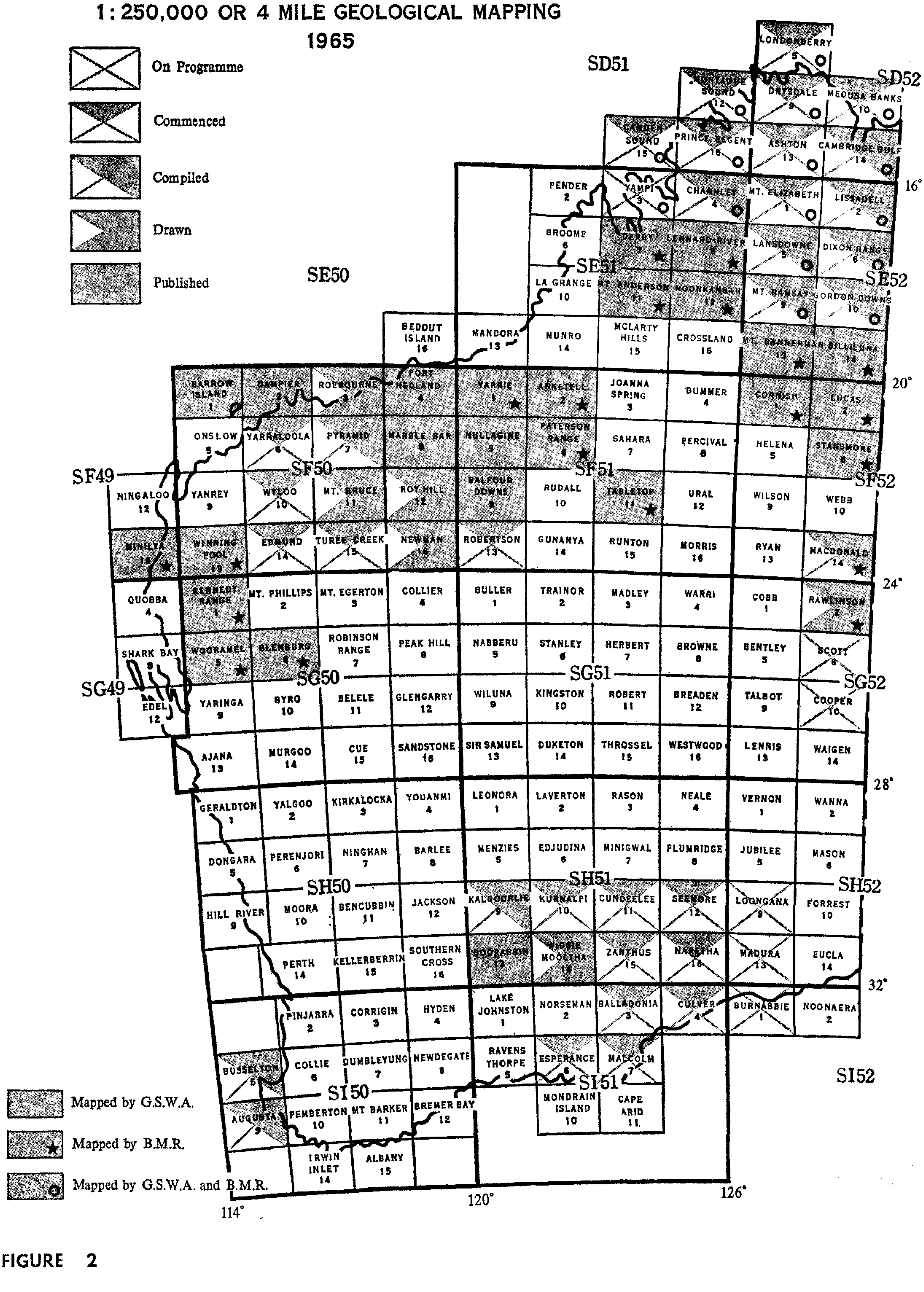

FIGURE 2

The use of palaeontology has proved most useful in correlations of results of drilling for groundwater particularly in the Perth Basin.

Geophysics (D. L. Rowston)

Hydrology and Engineering Division investigations again dominated the geophysical work during 1965. Forty-six water bores in the Gingin, Pinjar, Gnangara, Arrowsmith and Mandurah projects totalling 21,500 feet were logged with the Survey's Widco Logger. The logs have been used for lithological correlations and water salinity determinations. Resistivity measurements were made on 850 water samples submitted for field salinity tests.

A geophysical survey, employing gravity, magnetic and resistivity methods, was carried out in the Grasmere valley to assist a geological appraisal of further underground water supplies for the Albany township. Two seismic refraction surveys at the Gogo diversion dam site and the Fitzroy River bridge site near Fitzroy Crossing were made in conjunction with the Snowy Mountains Hydro Electric Authority for the Public Works Department.

Tests over beach sand deposits in the Capel area have shown that both scintillometer and magnetometer can detect concentrations of heavy minerals provided that they are near the surface and exceed about 6% heavy minerals.

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

Technical editing of reports, maps and plans continues to be the major function of this section. Two bulletins have been prepared for printing and the preparation of a booklet "Mineral Resources of Western Australia" is almost complete.

In anticipation of a quicker publication of the Annual Report, in some instances there has been no necessity to issue the results of a project as a Record and the number of these issued decreased slightly to 34.

The activity within the library is expanding rapidly. It is being used more extensively by the staff and also by exploratory and mining companies, established in this State. The loans from the library to staff increased by over 500 to 1,351 for the year. Loans to the public and other libraries increased from 203 to 600.

The number of requisitions raised for drafting and other services from the Drafting Branch increased from 523 to 696.

Public enquiry continues to increase, with an additional demand from petroleum and phosphate exploration companies for released but unpublished information compiled under the Commonwealth Petroleum Search Subsidy Acts.

The core librarian at the Dianella Store has received an increasing amount of material for storage as a result of the increased drilling for oil and water. Also many companies interested in the phosphate search have examined and tested samples from drill holes which are not classified as confidential.

ACTIVITIES OF THE COMMONWEALTH BUREAU OF MINERAL RESOURCES

The Bureau of Mineral Resources carried out both geological and geophysical work in Western Australia during 1965. The following projects were undertaken:

(1) Regional mapping of the Londonderry, Montague Sound, Drysdale, Medusa Banks, Camden Sound, Prince Regent, Ashton and Mt. Elizabeth 1:250,000 Sheets in the Kimberley Division, jointly with the Geological Survey of Western Australia.

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

(3) Low-level aeromagnetic survey (Cessna aircraft) of a small selected area near Kalgoorlie.

(4) Geophysical investigations for copper mineralisation near Ravensthorpe using magnetic, electro magnetic, and induced polarisation methods.

PROGRAMME FOR 1966

HYDROLOGY AND ENGINEERING DIVISION

Hydrology

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

(2) Hydrogeological investigation and/or exploratory drilling for underground water supplies in the following areas: Mandurah, Gnangara Lake, Arrowsmith River area, Albany, Esperance plains, Mullewa, Hopetoun, Port Hedland, Jurien Bay, Coomberdale, Midlands light lands, Carnarvon, Eucla Basin.

(3) Kimberley—hydrological assistance to pastoralists.
  (a) Bore site selection as required.
  (b) Regional hydrological mapping in conjunction with the Bureau of Mineral Resources.

(4) Miscellaneous minor investigations as requested by other departments and the public.

Engineering Geology

(1) Gogo Barrage Site—further investigations.

(2) Kennedy Range Dam Site—detailed investigation of site and parts of storage basin.

(3) Harvey Dam Site—supervision of diamond drill and assistance during construction.

(4) Standard Gauge Railway—investigations as requested and detailed mapping of cuttings.

(5) Ord River Dam Site—provide geological assistance if construction is undertaken.

SEDIMENTARY (OIL) DIVISION

(1) Maintain an active interest in the progress of oil exploration in Western Australia.

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

(3) Continuation of the geological survey of the Eucla Basin.

(4) Miscellaneous investigations as required.

REGIONAL GEOLOGY DIVISION

(1) Continuation of Eastern Goldfields mapping on the Kurnalpi 4-mile Sheet.

(2) Continuation of the regional mapping of the Kimberley Division in conjunction with the Bureau of Mineral Resources.

(3) Commencement of mapping on the Cooper and Scott 4-mile Sheets of the Eastern Division.

(4) Mapping of the Darling Scarp zone of the Pinjarra and Collie 4-mile Sheets.

MINERAL RESOURCES DIVISION

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

(2) Continuation of the investigation of the pegmatites of the Yalgoo and Murchison Goldfields.

(3) Miscellaneous investigations as required.

PUBLICATIONS AND RECORDS

During 1965 only three publications were issued but seven publications, including two bulletins, were submitted for printing.

Thirty-four Records were produced.

Issued during 1965

Annual Report for 1963 and 1964.

Geological Map of Port Hedland 1:250,000 Sheet (SF/50-4 International Grid) with Explanatory Notes.

In press

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

Geological Map of Roebourne 1:250,000 Sheet (SF/50-3 International Grid) with Explanatory Notes.

Geological Map of Roy Hill 1:250,000 Sheet (SF/50-12 International Grid) with Explanatory Notes.

Geological Map of Newman 1:250,000 Sheet (SF/50-16 International Grid) with Explanatory Notes.

Geological Map of Widgiemooltha 1:250,000 Sheet (SH/51-14 International Grid) with Explanatory Notes.

Bulletin No. 117, The Geology and Iron Deposits of the Hamersley Range Area, Western Australia.

Bulletin No. 118, Devonian Reef Complexes of the Canning Basin, Western Australia.

Geological Map of Western Australia 1:2,500,000.

Mineral Resources of Western Australia.

In Preparation

1:250,000 Geological Maps with Explanatory Notes, the field work for each having been completed: Pyramid, Turee Creek, Yarraloola, Wyloo, Kalgoorlie, Edmund, Robertson, Naretha, Culver, Busselton and Augusta.

Bulletin: Palaeontology of the Lennard Shelf, Canning Basin.

Records produced

No.	Author(s)	Title
1965/1	F. R. Gordon	Serpentine dam bywash spillway.
1965/2	F. R. Gordon	Seepage problems in cuttings near Northam, S.G.R. Contract Section C5, Avon Valley Deviation.
1965/3	J. L. Daniels and W. N. MacLeod	Explanatory notes on the Newman 1:250,000 geological sheet, Western Australia.
1965/4	F. R. Gordon and J. D. Wyatt	Geological investigations, Upper Wungong dam site.
1965/5	J. D. Wyatt	Detailed geology of the Ord River main dam site No. 2 (RESTRICTED).
1965/6	G. H. Low	Drilling of Upper Cretaceous glauconite deposits at Dandaragan, Gingin, and Bullsbrook.
1965/7	E. E. Swarbrick	Ord River main dam site No. 2 drilling programme, 1964 completion report (RESTRICTED).
1965/8	D. L. Rowston ..	Geophysical investigations over beach sand deposits, Capel area.
1965/9	A. D. Allen	Hydrogeology of the Lansdowne and Mt. Ramsay 1:250,000 geological sheets, Kimberley Division, W.A.
1965/10	J. Sofoulis	Explanatory notes on the Widgiemooltha 1:250,000 geological sheet, Western Australia.
1965/11	D. C. Lowry	Explanatory notes on the Busselton-Augusta 1:250,000 geological sheet.
1965/12	W. N. MacLeod	Ferro-manganese lode at Mt. Caudan, Yilgarn Goldfield.
1965/13	M. Kriewaldt and G. R. Ryan	Explanatory notes on the Pyramid 1:250,000 geological sheet, Western Australia.
1965/14	F. R. Gordon	An appraisal of No. 2 rock cut, Standard Gauge Railway, Avon Valley Deviation.
1965/15	A. D. Allen	The hydrogeology of the Allanooka area, Geraldton district, W.A.
1965/16	K. H. Morgan	Hydrogeology of the East Murchison and North Coolgardie Goldfields area.
1965/17	D. C. Lowry	Geology of the southern Perth Basin.
1965/18	F. R. Gordon	The stability of the Ainsworth railway cutting, Standard Gauge Railway project.
1965/19	F. R. Gordon and J. D. Wyatt	Geological investigations at Wungong Brook lower dam site.
1965/20	F. R. Gordon	Drilling investigations at Victoria dam (RESTRICTED).
1965/21	F. R. Gordon	A geological comparison of the Wungong Brook dam sites.
1965/22	J. D. Wyatt and E. E. Swarbrick	Engineering geology of the South Dandalup dam site preliminary appraisal.
1965/23	D. L. Rowston ..	Geophysical investigations for the Albany town water supply.
1965/24	P. Whincup	Exploratory drilling for underground water in the Pinjar area, Perth Basin, W.A.
1965/25	K. Berliat	An outline of the hydrogeology of the Balla—Dartmoor—Yuna area.
1965/26	J. D. Wyatt and E. E. Swarbrick	Geological investigation of the proposed Harvey dam site.
1965/27	D. L. Rowston ..	Fitzroy Crossing bridge site seismic investigations, September, 1965.
1965/28	W. N. MacLeod	Iron ore depot "A", Koolyanobbing, Yilgarn Goldfield.
1965/29	I. R. Williams	Explanatory notes on the Yarraloola 1:250,000 geological sheet, W.A.
1965/30	E. E. Swarbrick	Geological investigation of the Gogo diversion dam site.
1965/31	D. L. Rowston ..	Seismic survey of the Gogo diversion dam site.
1965/32	G. R. Ryan and J. G. Blockley	Progress report on the Hamersley Range blue asbestos survey.
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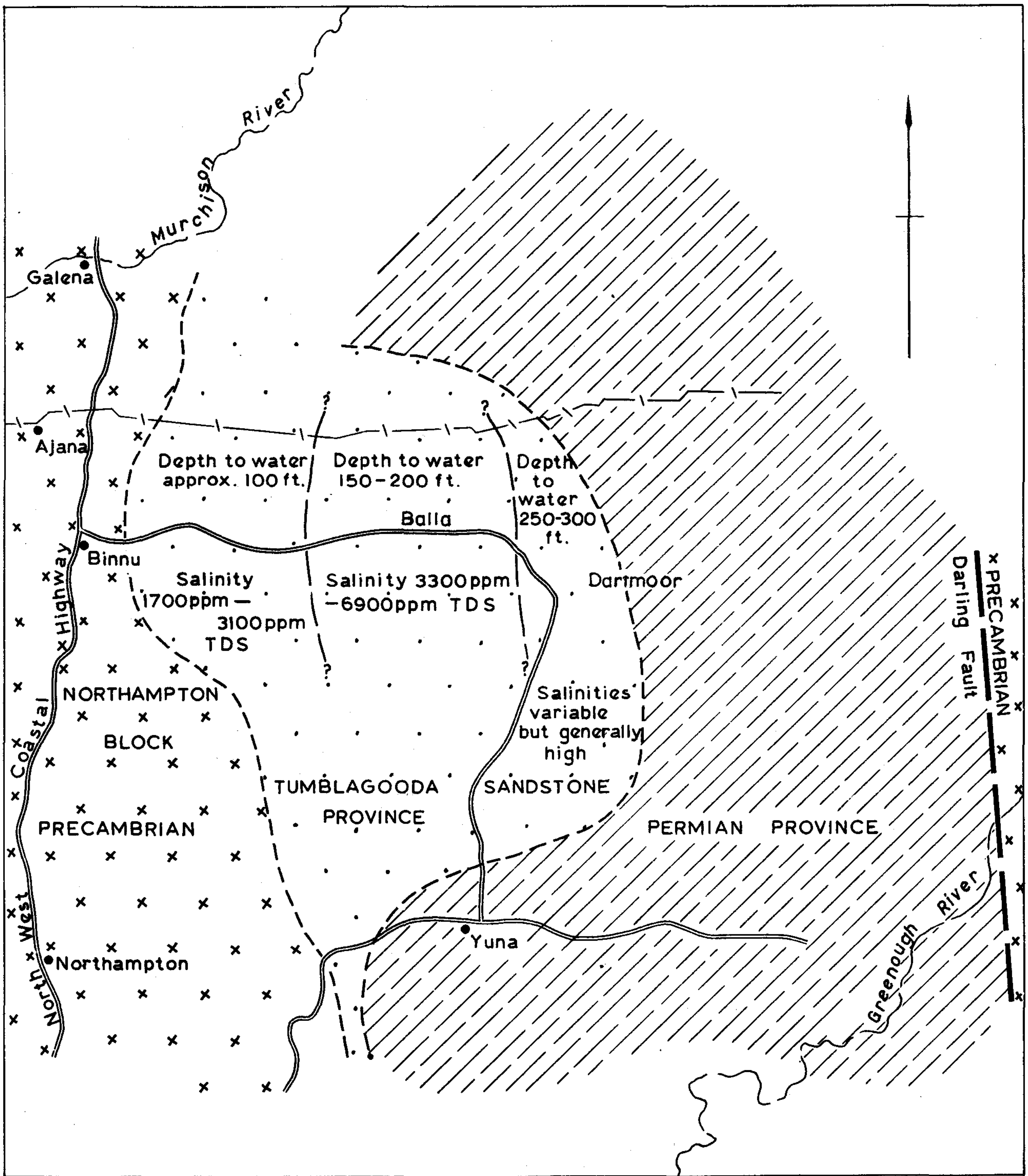


REFERENCE

Nangetty Formation, locally overlain by Holmwood Shale

Tumblagooda Sandstone, locally overlain by Holmwood Shale

Granitic rocks

Road, Highway

Geological boundary (approximate)

Hydrological sub-province boundary (approximate)

Rabbit proof fence No.3

SCALE OF MILES

8 0 8 16

GEOLOGICAL SURVEY OF WESTERN AUSTRALIA

HYDROGEOLOGY
OF
THE BALLA-DARTMOOR-YUNA AREA

To accompany report by K.Berliat 1965

8855

AN OUTLINE OF THE HYDROGEOLOGY OF THE BALLA—DARTMOOR—YUNA AREA

by K. Berliat

INTRODUCTION

At the request of local settlers, farm inspections were carried out in the Balla—Dartmoor—Yuna area to advise on prospects of obtaining groundwater for stock purposes. Rapid agricultural expansion is taking place, particularly in the Balla and Dartmoor districts, and although the conditions in general are more favourable than in many other farming areas, the provision of water supplies is nevertheless a critical factor. The development of some farms is seriously retarded by inadequate supplies, and at least one property has remained unstocked for many years because drilling has failed to locate usable groundwater. This is an area where geology is of fundamental importance in the search for groundwater, and many of the unsuccessful bores were wrongly located or not drilled deep enough. This report presents a regional picture of the hydrogeology.

The areas inspected lie to the east and northeast of Northampton (350 miles north of Perth). The farming centres of Balla and Dartmoor are centred about 32 miles northeast of Northampton, while Yuna is some 22 miles east of that town. Road access to Balla and Dartmoor from Northampton is via Yuna, or via Binnu on the Great Northern Highway (Plate 1).

TOPOGRAPHY, SOILS, RAINFALL

The Balla—Dartmoor area has an elevation of about 800 feet above sea level, and has a gentle regional slope towards the Greenough River in the southeast. The dominant topographical feature is a rolling plain, rising locally to hilly tracts. The area is part of the drainage system of the Greenough River, but surface drainage is poor and there are no significant permanent water courses. The greater part of the surface is covered by loose yellow sand and the remainder by pink or red clay. The annual rainfall is between 10 and 15 inches.

GEOLOGY

The area under discussion is in the central part of the northern end of the Perth Basin, which in this latitude has a width of about 45 miles. Bounded on the east and west by Precambrian rocks (Plate 1), the basin sediments have a slight regional dip to the east. The lower Palaeozoic Tumblagooda Sandstone is exposed along the eastern margin of the Northampton Block, and east of Binnu can be traced on the surface and in bores as far as Dartmoor, a distance of about 25 miles.

East of Dartmoor the Tumblagooda Sandstone disappears under a cover of younger Permian sediments, namely the basal, glacial Nangetty Formation and the Holmwood Shale, which locally overlies the Tumblagooda Sandstone west of Dartmoor.

Isolated outcrops of granite about 8 miles west of Balla, and also the granite reported in some bores between there and Balla, indicate a series of bedrock "highs", or possible faulting.

AQUIFERS

Aquifers are related to the main geological units recognized in the area.

Surface Deposits

The surface deposits consist of yellow sand and red clay. The most favourable conditions for the recovery of groundwater from surface sands are in an area extending from about 8 miles west of Balla to the Northampton Block, i.e., in the area west of the bedrock "highs" (or faults) previously mentioned. East of this belt the available supplies vary widely, even over small distances. Where the sand overlies Permian sediments, and where it is sufficiently thick and well drained, useful supplies are obtained from the contact zone. Where it overlies Tumblagooda Sandstone, most supplies are drawn from that formation.

The red clay is the weathering product of impervious Permian beds, and has proved to be an unsatisfactory groundwater prospect.

Holmwood Shale and Nangetty Formation

Because of low permeabilities, the Holmwood Shale and Nangetty Formation are generally not suitable as aquifers.

Local exceptions result from pervious horizons in a predominantly clayey succession. However, in most cases such intraformational layers have limited permeabilities, are of no great lateral extent, and recharge is restricted by the surrounding clay acting as a barrier to the effective movement of groundwater. This restriction of movement accounts for the very high salinities of most waters encountered in Permian sediments.

Tumblagooda Sandstone

Together with the surface sand, the Tumblagooda Sandstone is the main aquifer in the district. In outcrop, it consists of medium to coarse-grained, gritty sandstone, with thin conglomeratic layers. As the rocks are very old a high degree of cementation could be expected, but bore information shows that the top section at least is sufficiently permeable to allow considerable ingress and movement of groundwater.

DEPTH TO WATER AND SALINITY

Discussion of depth to, and salinity of, the groundwater has to be treated by reference to the two hydrological provinces recognized in the area, namely the Tumblagooda Sandstone Province and the Permian Province (Plate 1).

Tumblagooda Sandstone Province

The regional salinity pattern and the depth to water indicate a hydraulic connection between the surface sand and the underlying Tumblagooda Sandstone. In other words, the water table cuts across the two formations, and they are therefore treated as one hydrological unit.

Broadly speaking, the depth to water and the salinities increase from west to east. In the area east of Binnu and Dartmoor, where most of the investigations were carried out and where a considerable amount of bore data is available, three sub-divisions are distinguishable.

West of Balla the depth to water is about 100 feet, and salinities range from about 1,700 ppm to 3,100 ppm T.D.S. (120 to 220 grains per gallon).

In the Balla district water is encountered between 150 and 200 feet, with salinities ranging between 3,300 ppm and 6,900 ppm T.D.S. (230 to 480 grains per gallon).

In the Dartmoor area the depth to water is between 250 and 300 feet. Salinities are generally high, in many instances exceeding 10,000 ppm T.D.S. (700 grains per gallon). Groundwaters containing as little as 3,500 ppm T.D.S. (250 grains per gallon) do occur, but only exceptionally.

The conditions outlined above clearly indicate a general movement of the groundwater down dip, from west to east.

Permian Province

In the Permian province groundwater is obtainable from superficial sand overlying predominantly impervious strata. These sands are well developed over large tracts of country, and are up to 250 feet thick. Both depth to water and salinities are governed by local conditions, and there is no regional pattern. Groundwater of stock quality is generally available.

PRINCIPLES OF SELECTING BORE SITES

The following basic rules should be observed in selecting bore sites and during drilling operations.

(a) Sites should be selected in sandy terrains, and never in heavy clay country.

(b) In sandy terrain, search should be made for areas indicative of a deep sand profile, and which favour absorption of the rainfall.

(c) Other factors being equal, the sites should be selected as low as possible in the topography.

(d) Unless saline water is encountered, no bore should be abandoned in sand or easy drilling sandstone.

(e) Bores located in surface sands underlain by Permian clays should be continued to "blackjack" (again, unless saline water has been cut).

HYDROGEOLOGY OF THE EAST MURCHISON AND NORTH COOLGARDIE GOLDFIELDS

By K. H. Morgan

ABSTRACT

During the period 5th August to 14th November, 1964, inspections were made of 21 stations and two towns in the East Murchison and North Coolgardie Goldfields to advise on the prospects of obtaining additional groundwater supplies. The records of 600 water points were examined in an area covering 50,000 square miles, 172 new bore sites were selected, and a general appreciation of the regional hydrogeology was gained.

CLIMATE, PHYSIOGRAPHY AND GEOMORPHOLOGY

The climate is arid, with a rainfall of 8 to 10 inches falling mainly between January and June. In the northeastern sector most of the yearly rainfall results from thunderstorms between December and March.

The region falls mainly within the physiographic element named by Jutson (1950) as the Salt Lake Division or Salinaland, and is characterised by inland drainage terminating in salt lakes. To the west, near Cue and Meekatharra, the drainage has outlet to the sea and this area forms the eastern part of Jutson's Murchisonia region.

Almost the whole of the division has an elevation between 1,300 and 2,000 feet above sea level, and forms part of the Great Plateau of Western Australia. Elevations generally increase northwards from 1,400 feet at Mt. Magnet and 1,200 feet at Leonora to 2,100 feet in the Glengarry Range between Meekatharra and Wiluna. Railway levels are shown on Figure 3. The plateau has little relief. Dissected plains are the surface expression of deeply weathered granitic and basic metamorphic rocks. In places, stronger relief occurs in some metavolcanic and metasedimentary belts where the more closely spaced dendritic drainage pattern is controlled by south-southeast rock trends. Areas of strong relief, in the form of strike ridges and escarpments, are found in the younger Proterozoic sediments occurring between Meekatharra and Lake Wells.

The great plateau has two distinct elements: a higher, older level, called the old plateau, and a lower and younger surface, referred to as the new plateau.

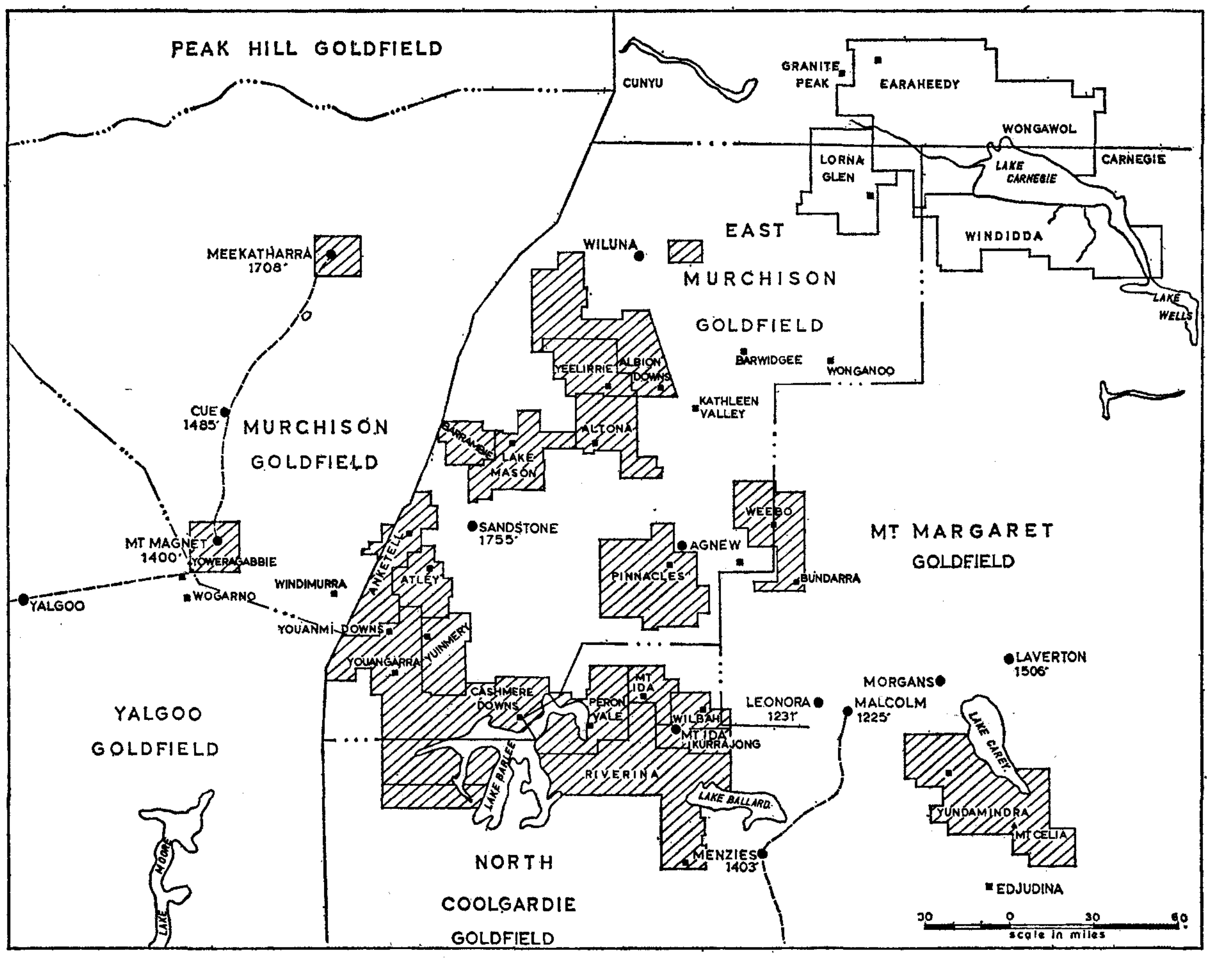


FIGURE 3: LOCALITY MAP EAST MURCHISON REGION SHOWING AREAS INSPECTED AND SOME LEVELS (by K.H. Morgan 1965)

The older plateau (Jutson, 1950; Mabbutt, 1963) is thought to have been a peneplain existing in pre-Eocene times. The drainage of this peneplain, the pattern of which is visible on the air photographs, was provided by three main river systems (Figure 4):

1. The main system for the North Coolgardie and Mt. Margaret Goldfields with an outlet to the southeast on an old coast near Zanthus, about 120 miles east of Kalgoorlie.

2. Westerly drainage along the old Murchison and Greenough Rivers. Following the development of the lower parts of these river systems in post-Miocene times, river capture took place, i.e., to the southeasterly drainage system via Lake Austin.

3. Southerly drainage from Mt. Magnet through Lake Moore to the old Avon river.

The old southeasterly drainage pattern was probably in existence in Cretaceous times, and predates a major marine transgression, more than 1,000 feet above present sea level, that inundated the land from the east to a line approximating longitude 123°E (Figure 4). This transgression probably continued in stages until Miocene times, as indicated by marine beds in Lake Cowan (Clarke, Teichert and McWhae, 1948) and deep lacustrine beds at Coolgardie (Balme and Churchill, 1959). By Miocene times the old plateau had become a peneplain and deep weathering and soil formation took place in a humid climate.

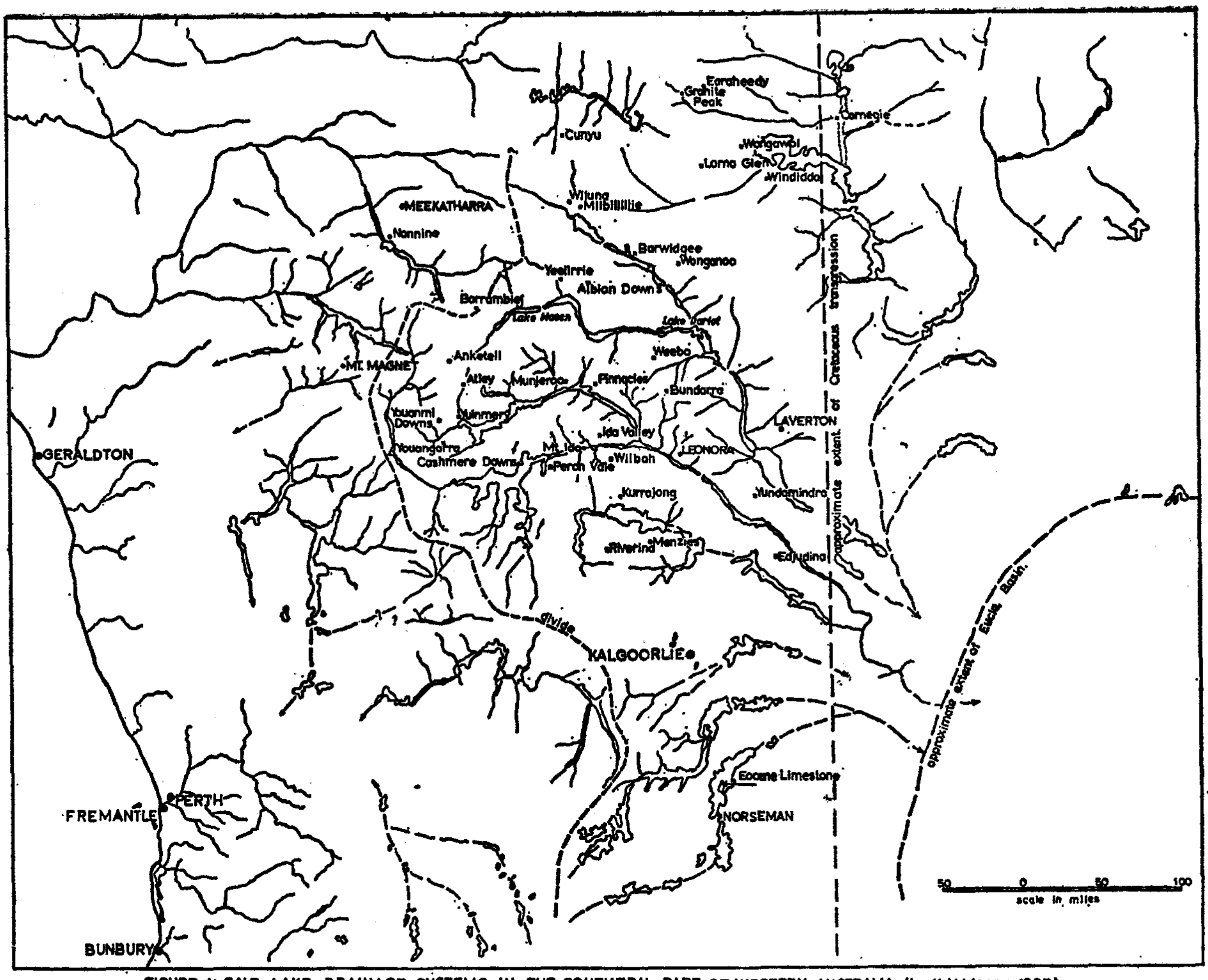


FIGURE 4: SALT LAKE DRAINAGE SYSTEMS IN THE SOUTHERN PART OF WESTERN AUSTRALIA (by K.H.Morgan,1965)

The second phase of development (late or post-Miocene), was one of marine retreat accompanied by southeastward tilting up of the Westralian Shield. The lowering of sea level or the upwarp of the land renewed active erosion, thereby narrowing and degrading the river valleys and sheet stripping the deep soils. Eventually this rejuvenated erosion cycle re-exposed rock belts, and produced the close, strike controlled, dendritic drainage on metamorphic rocks (e.g., Leonora, Menzies, Edjudina) and the more open patterns on granites. In the upper parts of the river systems and in the granite areas, erosion of old plateau has been mainly by breakaway retreat.

The new erosion cycle was soon checked by the onset of an increasingly arid climate which started a new phase of landscape development; one of arid erosion and alluviation. With reduced and spasmodic rainfall, the main rivers lacked energy to remove available sediments from the region, with the result that the main valleys filled with sediments, and storm waters were ponded to form evaporation pans. Alluvial fans were deposited by the smaller streams at their entry to the new plateau, and extensive thin sheets of alluvium were deposited over the new plateau surface.

With the check of erosion by the onset of an arid climate, extensive uneroded areas of the old plateau remain near the headwaters of the river systems. Dunes were formed on the old plateau remnants as a result of wind sorting of sand.

The old plateau is usually 30 to 100 feet, and occasionally as much as 200 feet, above the younger plains. It is now represented by sand plains, often terminating in breakaways, and with a cover of spinifex, sugar brother, spinifex gum and with cypress pine and desert poplars on sand dunes.

On the old plateau the high hills or monadnocks are usually capped by large round sandhills. The cores of such hills are of hard rock, which may be one of several types. Most hills are formed of fresh massive granite; but some hills correspond to jaspilite bands or Precambrian metasediments, and others to quartz blows or dykes, as were observed on Lake Barlee Station.

Intermediate between the old plateau and the new plateau are wide erosion areas or pediments with little or no soil cover, exposed as either fresh rock or the lower part of the laterite profile. Such pediments are characterised by weeping willows and cork trees on the hard rock drainages and York gum in the lateritic residuals. Alluvial fans are deposited on stream outlets on the lower side of these pediments and are typically covered by dense mulga growth.

The lower plateau forms extensive plains covered by a thin veneer of alluvium. The drainage lines are covered by dense mulga that gives way to buloke and salt lake herbage in the lower, more saline parts. Bowgada shrubs appear to be more common in areas underlain by greenstones.

Salt lakes now occur in the old river valleys within the new plateau, and overlie as much as 200 feet of sediments deposited during the arid alluviation cycle of the late Tertiary.

GENERAL GEOLOGY

The region forms part of the stable Western Australian Precambrian Shield. It is underlain by Archaean granite, and gneiss with belts of basic metavolcanic and metasedimentary rock, and relatively small remnants of little-altered Proterozoic sediments. There has been no systematic geological mapping, and recorded geological information is confined mainly to isolated gold mining centres.

METAMORPHIC BELTS

Metamorphic rocks occur in isolated north-northwesterly trending belts and often give rise to areas with stronger relief than the areas underlain by granitic rocks. The igneous and meta-igneous rocks include diorite, amphibolite, schist, and acid to basic volcanics, with massive and blocky, schistose, or foliated structures. These are interbedded with meta-sediments such as jaspilite and ferruginous quartzite. Often the lithology of the metamorphic rocks is not readily apparent and the general term greenstone has been widely applied. The metamorphic rocks are intensely folded, with dip and foliation generally steeper than 70°. On air photos the jaspilite and quartzite ridges often show complex folds. Schistose and foliated greenstones are generally deeply weathered.

GRANITE AND GRANITIC GNEISS

Granite is mainly medium to coarse grained and porphyritic; gneiss is finer grained, with gneissic structure developed by concentrations of biotite and magnetite. Pegmatitic lenses are common in all granitic rocks. Large intrusive masses of granite are usually surrounded by granite gneiss which, on air photos, shows a wide banded pattern resembling sedimentary bedding. Because of foliation and variations in mineral composition, the gneiss is more susceptible to weathering and erosion. Granite masses, because of their more uniform composition and relatively open jointing, are resistant to weathering and have remained as bedrock highs throughout geomorphic history. The granite occurs as bedrock highs under sand plains of the old plateau and sometimes forms rounded, sand-covered hills along the breakaways. In eroded areas of the new plateau, the granite forms hills of bare rock. Examples are Noondie Hill (Yuinmery Station), Malgar rock (Barlee Station), Mulline rock (Riverina Station).

PROTEROZOIC SEDIMENTS

The slightly altered Proterozoic sediments appear to be restricted to the northern area. These include a gently folded sequence of silicified sandstone, dolomite, shale, and basalt unconformably overlying the Archaean rocks. Prominent minor plateaux of Proterozoic rocks occur between Meekatharra and Wiluna and include Mt. Yagahong, 25 miles southeast of Meekatharra, rising 600 feet above the general level. A thicker sequence of folded Proterozoic rocks occurs in the Princess Range area, forming a prominent set of southeast-trending strike ridges. These rocks may be continuous with the sedimentary sequence in the Pilbara. Dolomite beds contain algal fossils.

TERTIARY AND QUATERNARY ROCKS

Rocks of the lateritic profile

The character of the laterite profile varies according to the nature of the underlying rock. The typical profile developed above granite, consists of an upper ferruginous layer overlying a white, leached, frequently porcelanised, "pallid zone" locally known as "breakaway rock". The pallid zone grades downwards into weathered then into unweathered rock. The thick ferruginous cap, so common in the southwestern part of the State is often absent. Granite structures and textures are preserved in the pallid zone cliffs and pediments.

Above greenstone, a thin, pisolitic surface layer overlies a thick pallid zone with a mottled white and red-brown zone near the water table. The upper part of the pallid zone frequently contains veins of green opaline silica.

Alluviated river valley and salt lake deposits

The main river valleys are often filled to depths of 50 feet or more with alluvium composed of ironstone rubble and gravel, and clayey, silty sand, frequently cemented with carbonates. In the lower parts of the main valleys and around the edges of salt lakes there is an increase in carbonate cement with the development of wide surfaces of kunkar or tufa limestone. At the level of the water table, carbonates are replaced in places by opaline silica. Pedologists refer to the carbonate-cemented deposits as calcretes. In soil mapping this has been particularly applied to the dissected benches of cemented alluvium on the sides of drainages.

Some salt lakes have deep deposits of saline, clayey alluvium with thin gypseous and salt bands. Such a deposit in Lake Way is over 150 feet thick.

Outwash fans and "Hard-pan"

Alluvial fans occur on most of the smaller streams at the point where they leave hilly ground and enter the wide, flat valleys. An extensive thin veneer of alluvium spreads over the new plateau surface from these fans. At a depth of 1 to 2 feet in non-saline alluvium there is a hard, red-brown, cemented layer known locally as cement, or by pedologists as ferricrete.

Eolian sands

Sand dunes occur on the sand plain of the old plateau and result from wind sorting of the residual sands from the top of the laterite profile. The dunes are linear to rounded or cusp-shaped and are composed of red, iron-stained quartz grains. The dunes have been stabilised by vegetation except for small localised blow-out areas. Sand and kopi (gypseous dust) dunes occur around salt lakes.

HYDROGEOLOGY

CRYSTALLINE ROCK

Water occurs in hard crystalline rocks in joints, fractures, gneissic foliation planes, selectively weathered contact margins, and cavities formed by selective weathering of minerals in veins and vugs. The amount of water present depends on the size and frequency of the rock voids, and its quality depends largely on the quality of intake water.

There are more rock voids near the contact of hard rock with soil or weathered rock (Figure 5, Diagrams 1, 2, 3) and as a general rule, most rock joints are too tight to transmit water at depths of 50 to 100 feet below the hard rock surface. Water is frequently found at much greater depths in mines, which are commonly situated in zones where fractures, contacts and easily weathered mineral veins allow water to penetrate to greater depths. At depth, such water is usually saline. In the Hill 50 mine near Mt. Magnet, potable water commonly occurs to a depth of 150 feet (the weathered rock extends to about 100 feet); water is localised and brackish at 1,000 feet; and highly localised occurrences of brine occur to depths below 1,400 feet.

Hills of exposed crystalline rock are excellent storm water catchments, and since rainwater runs directly into joints and fractures that have been opened at the surface by weathering, these hills become good intake areas. Exfoliation joints are important intakes on the rounded granite hills such as Noondie or Mulline rocks (Figure 5, Diagram 1 and Plate 2). Poorer intakes occur in the blocky jointing of dioritic rocks and quartzites (Figure 5, Diagram 2).

WEATHERED ROCK

Greenstones

The rocks generally known as greenstones are susceptible to deep weathering and usually produce impervious, puggy clay. These rocks yield poor supplies, often have an unexpectedly high water salinity, and the steep rock dip and cleavage tend to make drilling difficult. For these reasons greenstone areas present problems in groundwater search. Saline water is also often encountered in bores in weathered greenstone when the bore has been over-deepened because of poor supply in puggy clay e.g. Bottle Tree Creek Bore, Kurrajong Station.

Jaspilite-quartzite beds

Jaspilite-quartzite beds crop out strongly as strike ridges and are useful rainfall catchments. A blocky joint system opened by weathering allows the ready ingress of rainwater which moves down the steep dip of the beds (Figure 5, Diagram 2). However, the joint system closes at shallow depth and water cannot penetrate very far down into the rocks. Where quartzite and jaspilite are highly silicified they behave in a similar way to the crystalline rocks.

Weathered granite and granitic gneiss

Shallow groundwater supplies are frequently found in the outwash zone, composed of coarse, fresh granite fragments, around the periphery of

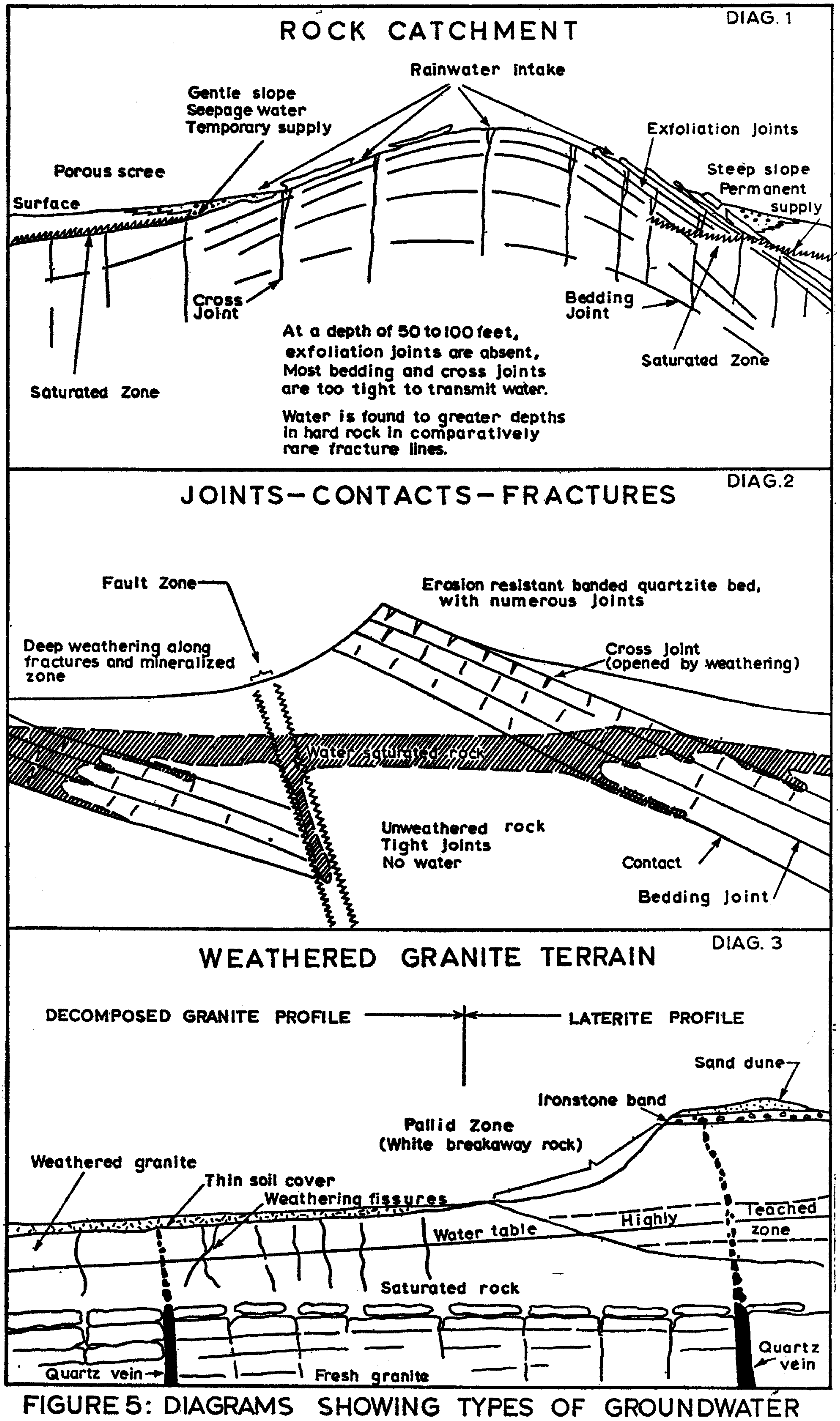


FIGURE 5: DIAGRAMS SHOWING TYPES OF GROUNDWATER OCCURRENCE IN THE EAST MURCHISON

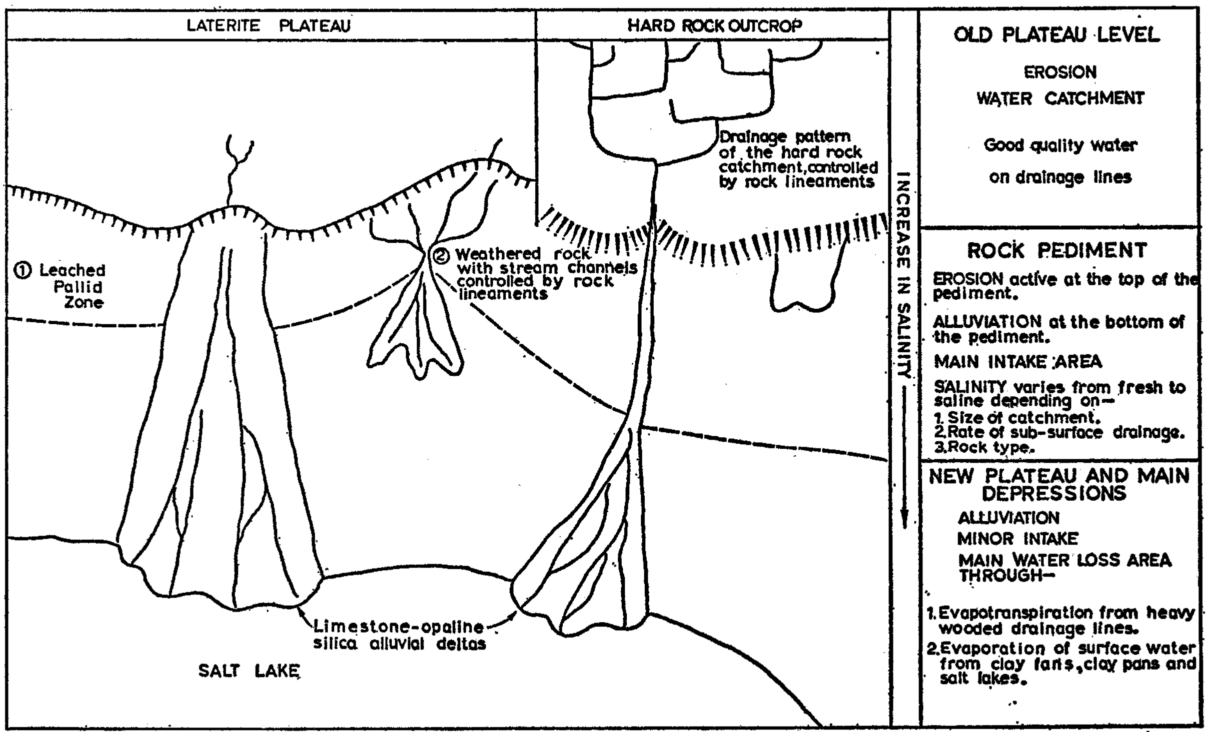


FIGURE 6: GROUNDWATER IN ALLUVIUM ; WATER BUDGET DIAGRAMS (by K.H. Morgan, 1965)

a granite hill (Figure 5, Diagram 1). These restricted storages are often subject to decline during drought, but nevertheless are valuable localised water supplies in saline areas.

As a rule, granite weathered "in situ" produces a relatively impervious clay, and supplies are obtained only from restricted water channels afforded by quartz veins and blocky quartzose pegmatite veins. These veins are common in granitic rocks, and because of the resistance of quartz to weathering, they remain as a hard framework when the granite and included minerals become weathered. A quartz vein, because of its competency, breaks into a series of angular blocks surrounded by soft and incompetent sandy clays. In wells, water is often observed issuing from these quartz stringers.

Other open channels containing water occur in the weathered granite profile, but their origin is unknown. The common practice of constructing drives at the bottom of wells enlarges the well storage and increases the chance of encountering these permeable channels.

LATERITE

Breakaways on lateritised granite act as catchment areas for rainfall (Figure 6; Plate 3). Rainwater is readily taken into the sandy soil, and, after heavy storms, soaks down through the highly permeable ferruginous zone. Deep weathering close to the breakaways allows cable tool drilling.

Leaching of the pallid zone produces an open quartz grain framework with high permeability. Strong leaching appears to be typical in the elevated northern part of the region and the irrigation supplies found at Albion Downs are from this source.

ALLUVIUM

As a rule, alluvium is clayey and carbonate cemented, and yields poor supplies of water. Clean, river sand beds are relatively rare. Large supplies of water may be found in rubbly ironstone gravel, in solution channels in limestone, and in the open box-work structures in limestone where there has been replacement by opaline silica. Limestone and opaline silica deposits are found in the slower-draining main valleys or on the lower parts of main tributaries, and are frequently close to salt lakes (Figure 6; Plate 5). In the Wiluna area these deposits yield irrigation quality water. Farther southwards towards Sandstone, limestone deposits are associated with saline water. Still farther southwards, in the Menzies—Lake Barlee area, limestone deposits do not occur in the main drainage lines. As a regional generalisation it can be stated that the limestone deposits usually contain the most saline water in their immediate locality because they occupy the lowest positions on any drainage line or alluvial aquifer. Limestone aquifers also contain water with undesirable properties such as high hardness, and a high content of nitrate and harmful salts, e.g. Lime Kiln Well, Lake Mason Station.

Groundwater salinity bears a consistent relationship to the inland drainage pattern. This can be generalised in the following way:

1. The primary river valleys (trunk valleys of the ancient drainage now occupied by salt lakes) all contain saline groundwater. In the more elevated areas, where there has been comparatively little erosion of the old plateau, there is better drainage towards lake depressions, and a corresponding rapid transition from fresh to saline water. Southwards there has been greater stripping of the old peneplain, elevation and river grades are lower, and there is a slower transition of better quality water to saline water on approaching the salt lakes. South from Lake Barlee all groundwater is brackish; useable water being found only in local catchments.

The Menzies Laverton area, although well downstream on the old drainage system, has in places moderately strong relief as a result of metamorphic belts. However, because of the weathering properties of these rocks, this area has remained saline.

2. Secondary drainages that lead into salt lakes, and occupy main branch valleys of the old drainage system in areas of good drainage from interfluves, contain brackish stock water. Where interfluve areas have slight relief, the drainages contain saline water. In the southern part of the region the secondary drainages are all saline.

3. Tertiary drainage lines, which cross the eroded area of the new plateau and have superposed tributaries, contain useable water north of Youanmi. South of this, all but minor drainage lines, direct from hill catchments, contain saline water.

ALLUVIAL FANS

Alluvial fans are readily recognisable on air photos by the distributary stream pattern and dense vegetation. On the ground the fans are characterized by dense scrub, clay-sealed soil surface and heaps of light, flood-washed debris (Plate 3, 4, and Figure 6). Three divisions of the alluvial fan drainage can be recognised:

(W.A. Lands Dept. photo WA 562Z, Run 17-5144)

Crystalline Rock Catchment (Mulline rocks, Riverina Station). These are monadnocks of intrusive granite. Drainage of storm water is shown on the photo by the dark lines of mulga, the directions of the drainage being controlled to some extent by joints in the granite.

PLATE 3

(W.A. Lands Dept. photo WA 661Z, Run 3-5137)

Breakaway Catchment: Pallid Zone Intake (Albion Downs Station). The top of the photo shows the old plateau surface with sand dunes above breakaways. Below the breakaways is a bare rocky pediment of pallid zone granite through which the streams have well defined channels. At the base of the pediment, near the centre of the photo, is the intake area at the top of the alluvial fan. The patches of cusp or bar-shaped vegetation patterns are always associated with intake of good quality water.

(W.A. Lands Dept. photo WA 666Z, Run 11-5111)

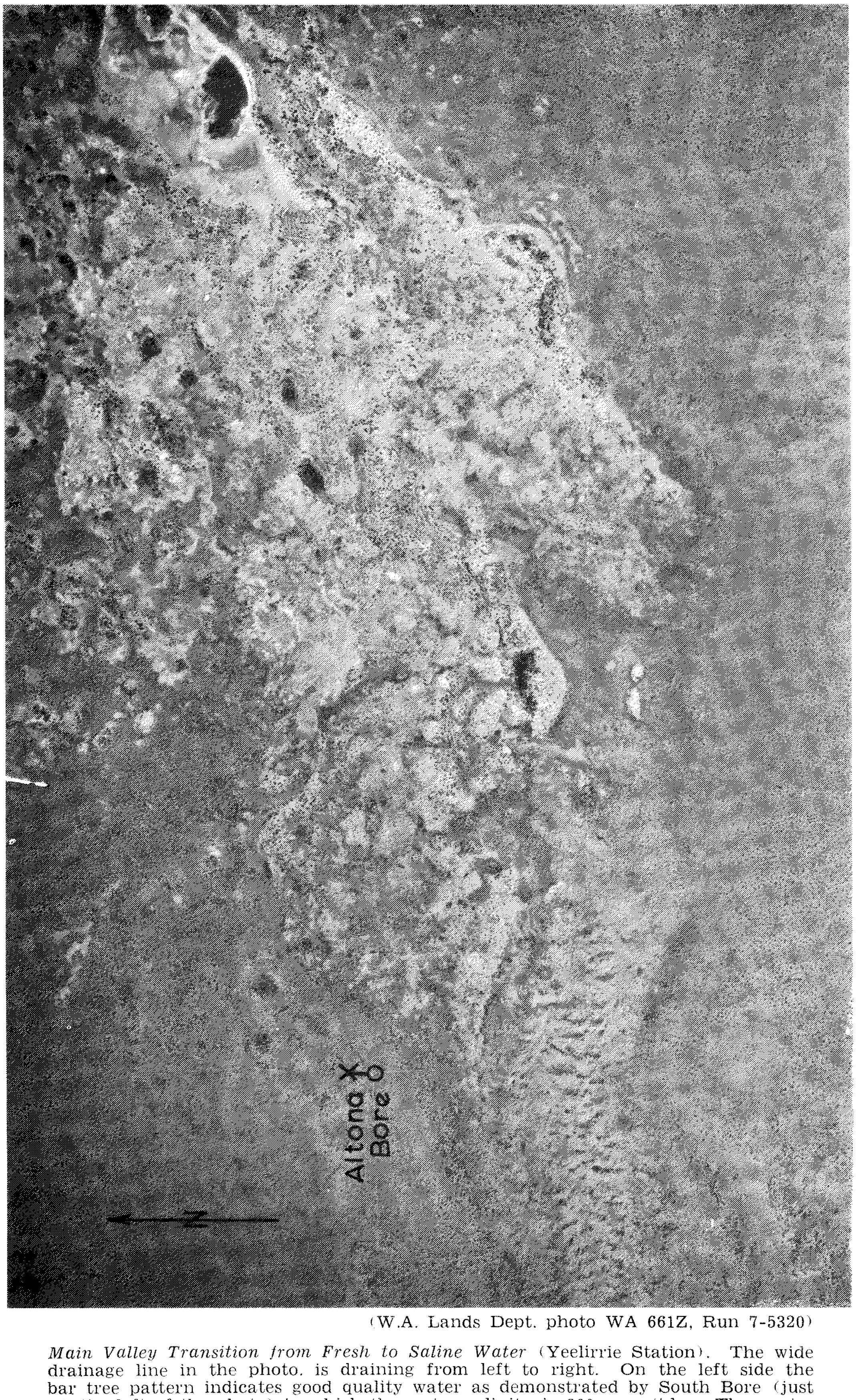
Morphology of an Alluvial Fan (Barrambie Station, 30 miles north of Sandstone).

1. Old Plateau: This is on the upper part of the photo and is the catchment area underlain by lateritised granitic rocks.

2. Pediment: This area of active erosion is shown on the centre of the photo as a light coloured bare patch. The area has a thin soil cover and many outcrops of slightly weathered granite. Streams have narrow channels and their pattern is controlled by hard rock lineaments. Intake of good quality water occurs on the lower edge of the pediment.

3. Alluvial Fan: This is shown on the lower left part of the photo and can be distinguished by the distributary stream pattern and dense mulga scrub. The alluvial fan has low intake because of the surface clay seal. Most of the water is lost by evaporation and transpiration. In the lower part of this fan groundwater becomes very brackish.

PLATE 5



(W.A. Lands Dept. photo WA 661Z, Run 7-5320)

Main Valley Transition from Fresh to Saline Water (Yeelirrie Station). The wide drainage line in the photo. is draining from left to right. On the left side the bar tree pattern indicates good quality water as demonstrated by South Bore (just off the left of the photo) in which the water salinity is 900 ppm./tds. The centre of the photo shows a change to limestone, cemented alluvium and brackish water (i.e. salinity approximately between 1,500-10,000 ppm./tds.). Altona Bore has a salinity of 2,000 ppm./tds. On the right side of the photo the circular patterns indicate saline soils, and the groundwater is brackish to saline.

1. Catchment Area. This is a remnant of the old plateau surface. Where hard rock is exposed, as in areas of younger Precambrian sediments or over granite outcrops, the drainage has well defined channels and the pattern is controlled by hard rock lineaments. Where the catchment is composed of lateritised granitic rocks and sand plain, drainage is mainly in the subsurface. Numerous gnamma holes occur on the top edges of breakaways and are filled by seepage water.

2. Rock Pediment. This is an eroded rocky area below the old plateau surface where numerous outcrops of truncated pallid zone or slightly weathered rock occur. Drainage lines are well defined and the pattern is controlled by rock lineaments. Since numerous rock fissures are exposed, or underlie a thin veneer of soil, the lower part of the pediment is an important intake area. Frequently a distinct bar or cusp-shaped air photo pattern of trees occurs on the wide drainage lines crossing the pediment, or in isolated patches, (Plates 3 and 5) and these are always associated with intake of fresh water.

3. Alluvial Fan. These fans occur where the grade of the minor drainage line suddenly decreases on the new plateau surface. Because of the clay seal, there is little downward percolation of flood water into the permeable outwash alluvium. Most of the water is lost by evaporation and used by plants. The upper sections of alluvial fans are sources of small local accumulations of stock water in saline areas. A stream catchment one mile long can provide enough intake for a stock bore in an otherwise saline area. Some of the larger alluvial fans extend as deltas into salt lakes (Figure 6); the water table rises to within a few feet of the surface and the presence of saline water is indicated by buloke trees and limestone.

There is a marked increase in groundwater salinity in a downstream direction from the pediment and through all alluvial fans. Water salinity in an alluvial fan may increase from potable to saline within a quarter of a mile, whereas in other cases, stock water may be found in the delta areas on salt lakes. The rate of increase in salinity depends on size of catchment, effectiveness of intake, amount of drainage and leaching, and underlying rock type.

UTILIZATION OF GROUNDWATER

With the decline in gold mining and consequent depopulation of towns, groundwater supplies are now utilized mainly by the pastoral industry. Nearly all available land is covered by pastoral leases, which range in size from 100,000 to 1,000,000 acres. Stations are fenced and divided into paddocks and stock watering is controlled in this way. Since stock density averages one sheep to 40 or 50 acres, stock bores equipped with wind pumps yielding 1,000 to 4,000 gallons per day are adequate. At this stock density there is little likelihood of future shortage of stock water reserves.

The number of water points on individual stations ranges from four to eighty, and reflects the state of development and the value of the pasture.

All early water supplies were from rock holes and wells, and, although wells probably still outnumber bores, the high cost of well repair and construction has resulted in drilling becoming more popular in recent years.

Stock bores have been relatively easy to find for initial development. Now only some of the poor pasture areas, or those with hard rock at shallow depth or salt water, require stock water points. Several instances have been recorded where as many as 20 bores have been drilled in difficult areas, to obtain one successful bore.

A few stations have made use of the larger supplies of water for irrigation of fodder crops. Generally small crops of 5 acres of lucerne are maintained and these require about 90 inches per acre per year of irrigation water. Some irrigation bores yield between 5,000 and 20,000 gallons per hour.

Many extensive aquifers with irrigation potential occur, particularly in the northern part of the region. However, the high capital cost of irrigation deters most pastoralists from making use of irrigated fodder crops as a reserve against drought.

It is quite possible that the larger storages of available groundwater could be developed for other irrigation crops and thus provide an important new phase of development in the region.

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HYDROGEOLOGY OF THE PINJAR EXPLORATORY DRILLING

by P. Whincup

ABSTRACT

Seven exploratory water bores, varying in depth from 1,142 to 2,160 feet were drilled 20 miles north of Perth, in an east-west direction from Bullsbrook to Quinns Rocks across the Perth Basin.

The oldest sediments penetrated are garnetiferous sandstones believed to be of Upper Jurassic age although they may be younger in part. From electric logging and hydrological data they are correlated with the Claremont Sandstone; palynology cannot confirm this correlation.

These older sediments are disconformably overlain by Lower Cretaceous sediments in which two units are distinguishable, an upper Leederville Sandstone unit and a lower South Perth Shale unit. Several thin calcareous beds near the contact of these units proved to be good marker beds. The marine Upper Cretaceous Osborne Formation is found only in the eastern part of the Basin and unconformably overlies the Leederville Sandstone.

The Jurassic and Lower Cretaceous beds have a shallow dip to the southeast with a reversal in dip near the coast; the Upper Cretaceous beds are flat-lying. Post-Cretaceous movement along the western margin of the Darling Fault Zone has uplifted the sediments which overlie the zone by approximately 500 feet.

Aquifers of Quaternary, Upper Cretaceous, Lower Cretaceous and Upper Jurassic age were encountered. The shallow, unconfined Quaternary aquifer yields domestic quality water. The Upper Cretaceous aquifer is limited in extent and yields only small supplies of good quality pressure water. The Leederville Sandstone and South Perth Shale aquifers are separated by the thick siltstone of the upper marine unit of the South Perth Shale. Large supplies of good quality pressure water occur in the Leederville Sandstone, the salinity increasing with depth in the eastern bores. Directly west of Lake

Pinjar, and to a lesser degree west of Neerabup Lake, the upper part of the aquifer is contaminated by brackish water. Recharge is apparently effected by seepage along the Darling Scarp, and in the centre of the Basin by leakage from the overlying Quaternary aquifer. The South Perth Shale aquifer occurs only towards the east, contains good quality water, and may be in continuity with the underlying Jurassic aquifer.

The Claremont Sandstone aquifer is subartesian to artesian, yielding large supplies of domestic quality water in the central bores and good stock quality water to the east and west. The aquifer is considered to extend southwards to the Perth Metropolitan area. Recharge occurs northeast of Pinjar, near the Darling Scarp, but the nature of the intake is not known.

INTRODUCTION

This report discusses the results of a drilling programme carried out by the Mines Department in the Perth Basin about 20 miles north of Perth between March, 1964 and August, 1965. A full summary of the results is given in Geological Survey of Western Australia Record 1965/24. A line of deep bores was drilled by rotary methods in an east-west direction across the Perth Basin from Bullsbrook in the east to Quinns Rocks Townsite in the west, a distance of about 20 miles. Seven bores were drilled, varying in depth from 1,142 feet to 2,160 feet, the total footage drilled being 12,610 feet. Results from a percussion bore drilled to a depth of 1,420 feet at the Pearce R.A.A.F. base in 1959 are included.

The drilling is part of an investigation of the hydrogeology of the Cretaceous and Jurassic sediments in the Perth Basin. Two similar projects, already completed by the Mines Department at Byford and Mandurah, intersected the Lower Cretaceous aquifers south of Perth. In the Metropolitan area however, Jurassic sandstones are the most prolific aquifer and the main objective of the Pinjar drilling was to test their extent and assess possible intake areas.

Hydrological information was collected by use of a Johnston Formation Tester and much useful data were also obtained by electric logging. Some palynological work has been done on selected core samples.

GEOLOGY

GENERAL

The Perth Basin is a narrow trough about 600 miles long, bounded on its eastern margin by the Darling Fault. A gravity survey over the basin by Thyer and Everingham (1956) suggests that the Darling Fault is a major, steeply dipping, normal fault separating the crystalline rocks of the Precambrian Shield from the sediments of the basin. The maximum accumulated thickness of sediments is estimated to be not less than 40,000 feet.

PREVIOUS WORK

A seismic traverse by Walker and Raitt (1964) was complementary to the drilling programme and roughly follows the east-west Pinjar line. Reflections above 2,500 feet indicate a shallow synclinal structure with the axis trending in a northeast direction, the deepest part of the syncline occurring a few miles from the eastern margin of the basin. An area of special interest near the basin centre shows possibly conformable beds overlying an apparent earlier erosion surface at 2,000 to 2,500 feet. More detailed seismic work (1965-66) by West Australian Petroleum Pty. Ltd. shows the erosion surface to be in the form of a scarp face dropping steeply to the west and appearing to have a total relief of about 2,000 feet. The surface can be traced at least 50 miles north and south of Pinjar. A gravity survey in 1963, by West Australian Petroleum Pty. Ltd., indicates a distinct anomaly trending northeast in the same position representing either a fault, with downthrow to the west, or an erosion surface.

Geophysical evidence on the position of the Darling Fault east of the drilling area is conflicting. A brief gravity survey near Bullsbrook by Thyer (1951) gives its position as half a mile east of the Great Northern Highway and the seismic evidence places the fault two miles east of the Highway. In a reappraisal Rowston suggests that both faults exist, the westerly one being overlain by 2,000 to 3,000 feet of sediments.

The oldest sediments penetrated in the Metropolitan area are sandstones of Jurassic age for which Fairbridge (1953) proposed the name Claremont Sandstone. The age of the beds in the type section, the Claremont No. 2 Bore has been determined by Balme as Oxfordian—Kimmeridgian. The depth to the Claremont Sandstone in the Metropolitan area ranges from 1,750 feet below sea level at Balcatta (4 miles north of Perth) to 2,450 feet below sea level at Jandakot (10 miles south of Perth).

In the Pinjar bores a thick sandstone sequence was intersected below the South Perth Shale and on palynological evidence was initially correlated with the Claremont Sandstone. More recent work suggests that it is younger than the sequence in the type section. However, the name Claremont Sandstone has continued to be used in this report to describe the sandstone underlying the South Perth Shale; the close resemblance on gamma-ray logs between the Lower Cretaceous and ?Jurassic sediments in the Pinjar No. 3 and Balcatta No. 2 Bores tends to justify this usage.

At Gingin, 50 miles north of Perth, Jurassic sandstones intersected at a depth of 3,200 feet below sea level, in a deep well recently completed by West Australian Petroleum Pty. Ltd., may be equivalent to the Claremont Sandstone in the Metropolitan area.

STRATIGRAPHY AND LITHOLOGY

Sediments of Quaternary, Upper Cretaceous, Lower Cretaceous and Upper Jurassic age were penetrated (see Table 1). Stratigraphic and lithologic correlations are shown on Plate No. 6.

Table 1

Age		Formation		Thickness in feet in each bore (bores west to east)							
				No. 6	No. 5	No. 4	No. 3	No. 2	No. 1	Pearce 3	No. 7
Pleistocene to Recent		Surficial Deposits		133	222	302	196	235	205	155	88
Upper Cretaceous		Osborne Formation		....	....	....	....	75	370	200	....
Lower Cretaceous	?Aptian	Leederville Sandstone		503	381	485	690	810	567+	1065+	1062
	?Neocomian	South Perth Shale	marine	489	429	455	294	170	....	....	....
			non-marine	....	....	....	273	570	....	....	808+
Upper Jurassic		Claremont Sandstone		875+	817+	474+	324+	300+	....	....	....

Quaternary

The Quaternary sediments have two sources. In the east they consist of alluvial sands and clays derived from the Darling Range and, in the west, of eolian limestone and dune sands.

They unconformably overlie the Cretaceous sediments, the depth of the unconformity varying from 103 feet below sea level in the west to 125 feet above sea level in the east.

Upper Cretaceous

The Upper Cretaceous sequence is equivalent to the Osborne Formation described by McWhae and others (1958). Its age in the Pinjar bores has been determined by H. S. Edgell as Cenomanian. It occurs only in the eastern part of the Basin and consists of dark green to black, glauconitic and pyritic sand and clay. A borehole for glauconite on the Darling Scarp, one mile southeast of Bore No. 7 and about 130 feet higher in elevation, also penetrated the Osborne Formation.

The formation was deposited under shallow marine conditions and rests on the eroded surface of the Leederville Sandstone.

Lower Cretaceous

The Lower Cretaceous sediments consist of an upper and a lower unit corresponding to the Leederville Sandstone and South Perth Shale of Fairbridge (1953). Palaeontological evidence suggests that they may be respectively Aptian and Neocomian in age. At the boundary between the two units several thin calcareous beds are developed which have proved to be good marker horizons across the basin.

A wedge of marine sediments, represented by the upper, dark grey, shelly siltstone sequence of the South Perth Shale, thins and finally disappears towards the east, being overlain and underlain by more continental sediments. The overlying Leederville Sandstone shows a similar decline of marine influences towards the east and in addition, a decrease in marine characteristics from bottom to top in the sequence.

The *Leederville Sandstone* is a grey, coarse, sandy sequence containing feldspar, pyrite, mica and carbonaceous material. Siltstone and shale are normally poorly developed, and least common in the centre of the area; east and west of this point they are better developed because of the increasing influences of continental and marine environments respectively. They are dark in colour and micaceous.

Marine influences increase with depth and, on the basis of lithology, the sequence over most of the area can be subdivided into two or three units. In the upper ones grains are subangular, and carbonaceous material and lignite are common. In the lower units the grains are more rounded, carbonaceous material is rare, and shell debris, traces of glauconite, and green quartz staining become evident, while the proportion of brownish and greenish siltstones and shales increases.

Towards the Darling Range the Leederville Sandstone becomes very clayey and no subdivision is possible. The clays range in colour from dark grey to light green and white; lignite, plant remains and less commonly lateritic fragments occur throughout, and there are no traces of marine influences. The sequence is micaceous and feldspathic and contains numerous fragments and boulders of gneissic and schistose rocks.

The marine section of the *South Perth Shale* is a dark grey, micaceous, clayey siltstone, containing shell fragments, pyrite and rare carbonaceous material. Calcareous beds are frequent near the contact with the Leederville Sandstone but also occur lower down. They are grey, greenish and brownish limestones, calcarenites and calcareous siltstones. Increasing continental influences towards the east are marked by an influx of sand, the presence of carbonaceous material and the absence of shell fragments in the upper part of the unit.

The underlying non-marine section is predominantly light grey-green in colour and is carbonaceous and micaceous throughout, the silt content increasing considerably towards the east.

Upper Jurassic

The Upper Jurassic sediments are predominantly non-marine and are correlated with the Claremont Sandstone described by Fairbridge (1953). Balme has identified an Upper Jurassic micro-floral assemblage from the type section and considers the formation in the Pinjar bores to be younger, probably Lower Cretaceous—Upper Jurassic in age. Edgell suggests an Oxfordian—Tithonian age for the Claremont Sandstone in the Pinjar bores.

Typically the sequence is a coarse to conglomeratic, cross-bedded, feldspathic sandstone containing carbonaceous material, garnets, ilmenite, siderite, pyrite and kaolinitic material. The sandstone is light-grey, rarely brownish and greenish, with subangular to angular grains and blue, green and yellow quartz-staining common. Minor thin beds of dark, micaceous and carbonaceous siltstone and shale occur. Kaolinitic material increases towards the coast.

The sequence in Bore No. 2 is of particular interest because geophysical evidence suggests faulting or erosion at a depth of about 2,000 to 2,500 feet. From 1,860 to 2,000 feet light-green sandstone and dark-green shale were penetrated. The sandstone is fine to medium-grained, garnetiferous and micaceous with subrounded grains. At 2,000 feet there is a 10-foot pebble band with rounded pebbles of siltstone and green quartz, the siltstone being very hard, dark green, calcareous and glauconitic. From 2,010 feet to the total depth of 2,160 feet, green, fine-grained, well sorted sandstone containing abundant glauconite, calcareous material and rare limestone with shell fragments was penetrated. Palaeontological work suggests that the glauconitic sands are younger than strata at similar depths in bores to the west. Hence the erosion surface lithologically evident at 2,000 feet is possibly only a relatively minor feature. The major erosion surface indicated by the geophysical work may in effect occur at a depth greater than 2,160 feet. On the evidence available it is suggested that erosion represented at a depth below 2,160 feet resulted in a marine incursion from the southwest and the deposition of the glauconitic sands. At the close of marine sedimentation erosion again took place this being represented by the pebble band at 2,000 feet.

East of Bore No. 2 there is no information on the Claremont Sandstone. Garnets, in the lowermost part of the South Perth Shale in Bore No. 7, may be reworked from the Claremont Sandstone, indicating a possible depth for the formation of between 1,950 and 2,000 feet below the surface.

STRUCTURE

A structural and geological interpretation across the Basin is shown on Plate No. 7.

Correlation of electric logs suggests that the Claremont Sandstone is overlain with a slight disconformity by the South Perth Shale. In Bore No. 2 a northeast-striking erosion surface may occur in the Claremont Sandstone at a depth of between 2,160 feet and 2,500 feet. The South Perth Shale is overlain conformably by the Leederville Sandstone. The Osborne Formation is a flat-lying sequence deposited on the eroded surface of the Leederville Sandstone. The Lower Cretaceous and Jurassic beds have a gentle dip of about ½° to the southeast. Near the coast it is postulated that the dip is reversed to the northwest although the possibility of faulting between Bores Nos. 5 and 6 cannot be precluded.

The eastern margin of the basin is delineated by a fault zone approximately four miles wide, the major displacement occurring on the western margin of the zone. It is noteworthy that at Byford a major fault was intersected four miles west of the Darling Fault. Across the fault zone as much as 2,000 to 3,000 feet of sediments may overlie the Precambrian crystalline rocks.

There is evidence of post-Cretaceous movement along the western margin of the fault zone. Thus, in the Bullsbrook Glauconite Hole the eroded top of the Osborne Formation is about 350 feet higher than in the Pearce bore. In Bore No. 7 the absence of the Osborne Formation can be readily explained by erosion following an upward displacement east of the Pearce bore. If the sediments had been merely uptilted against the fault the thickness of Osborne Formation in Bore No. 7 would be about 150 feet. Further evidence is provided by the position of the calcareous marker beds in Bore No. 7, approximately 500 feet stratigraphically higher than in the Pearce bore. It is suggested that in post-Cretaceous times movement took place along the western margin of the fault zone, uplifting the sediments about 500 feet to the east.

In the area south of Pinjar, contours on the bottom of the South Perth Shale (Plate No. 8) suggest that a fault, with downthrow of at least 1,500 feet to the west, occurs between Garden and Rottnest Islands.

HYDROLOGY

AQUIFER SYSTEMS

Aquifers occur in formations of Quaternary, Upper Cretaceous, Lower Cretaceous and Upper Jurassic age. The Lower Cretaceous and Upper Jurassic aquifers extend at least as far south as the Perth Metropolitan area where they are utilised by numerous bores.

Quaternary

The Quaternary aquifer is shallow and unconfined and consists of surficial sand and eolianitic limestone. It has been studied in detail, immediately south of the Pinjar area, by Morgan (1964). In Bores Nos. 1, 2 and the Pearce bore it is underlain by the Osborne Formation but elsewhere a thin, claystone aquiclude separates it from the Leederville Sandstone aquifer. Near Lake Pinjar and along the Darling Scarp the two aquifers are connected.

Upper Cretaceous

The Upper Cretaceous Osborne Formation aquifer appears to be of low permeability and in direct contact with the overlying Quaternary aquifer. Lithologically it consists of dark-green, fine to medium-grained, clayey sandstone containing abundant glauconite.

Lower Cretaceous

There are two distinct Lower Cretaceous aquifers, corresponding to the Leederville Sandstone and the lower, sandy, non-marine unit of the South Perth Shale, separated by the upper, marine, siltstone unit of the South Perth Shale. Towards the east the siltstone unit thins appreciably and the two aquifers appear to be connected near the Darling Scarp.

The *Leederville Sandstone* is an extensively developed confined aquifer, having a thickness in excess of 1,000 feet in the more easterly bores. It comprises grey, very coarse, feldspathic sandstone with interbedded shale and siltstone. Towards the east the permeability of the aquifer is lowered by an increasing clay content. In the western part of the area hydraulic and salinity patterns are considerably influenced by Lake Pinjar.

The *South Perth Shale* aquifer is developed only in the east. The clay content increases towards the scarp and in Bore No. 7 the aquifer is not more than 30 feet thick.

Upper Jurassic

The Claremont Sandstone aquifer consists of light-grey, coarse, feldspathic and garnetiferous sandstone, in parts conglomeratic. In the westernmost bores appreciable amounts of kaolinitic material decrease the permeability. In Bore No. 2 the aquifer consists of green, fine-grained, glauconitic sandstone deposited within an erosion channel; it may have no connection with the main aquifer.

The aquifer was not fully penetrated in any of the bores.

YIELD

No pump tests were carried out during the drilling programme. Forman (1933) gives the following information from bores in the Metropolitan area:

Aquifer	Maximum Yield (million) gal/day)
Leederville Sandstone	1.4
South Perth Shale	0.4
Claremont Sandstone	3.5

The Byford drilling showed that pumped yields of between 25,000 and 45,000 gallons per hour may be developed from the Leederville Sandstone aquifer.

DIRECTION OF GROUNDWATER MOVEMENT AND INTAKE AREAS

Quaternary

The Quaternary aquifer extends south to the Metropolitan area and perhaps as far north as Gingin. In the Pinjar area it is a source of recharge to the Leederville Sandstone aquifer. The predominant direction of groundwater movement is towards the southwest. The water table profile (Plate No. 8) suggests that the main intake for the aquifer occurs north of Bore No. 2.

Upper Cretaceous

A static water level of 221 feet above sea level was recorded from the Osborne Formation aquifer in Bore No. 2. As the water table at this point is 230 feet above sea level, it seems probable that the aquifer is in direct contact with the Quarternary aquifer.

Lower Cretaceous

Leederville Sandstone aquifer: The thickness and discontinuity of beds within the aquifer make precise correlation across the basin difficult. However the static water levels measured at the top of the aquifer in each bore are roughly from the same horizon and give the general shape of the piezometric surface (Plate No. 8). The static head decreases markedly with depth.

The hydraulic gradient shows a general fall from east to west indicating an intake along the Darling Scarp. Near the centre of the basin, leakage from the Quaternary aquifer is marked by a rise in the piezometric surface. In both areas the Osborne Formation, which acts as an aquiclude in the eastern bores, is missing and the Quaternary and Leederville Sandstone aquifers are separated only by thin claystone beds.

South Perth Shale aquifer: The direction of water movement and intake areas for this aquifer cannot be deduced from the information available. In Bore No. 2 it has a static head corresponding to that of the Leederville Sandstone aquifer whereas in the Metropolitan area it appears to be related to the Claremont Sandstone aquifer.

Upper Jurassic

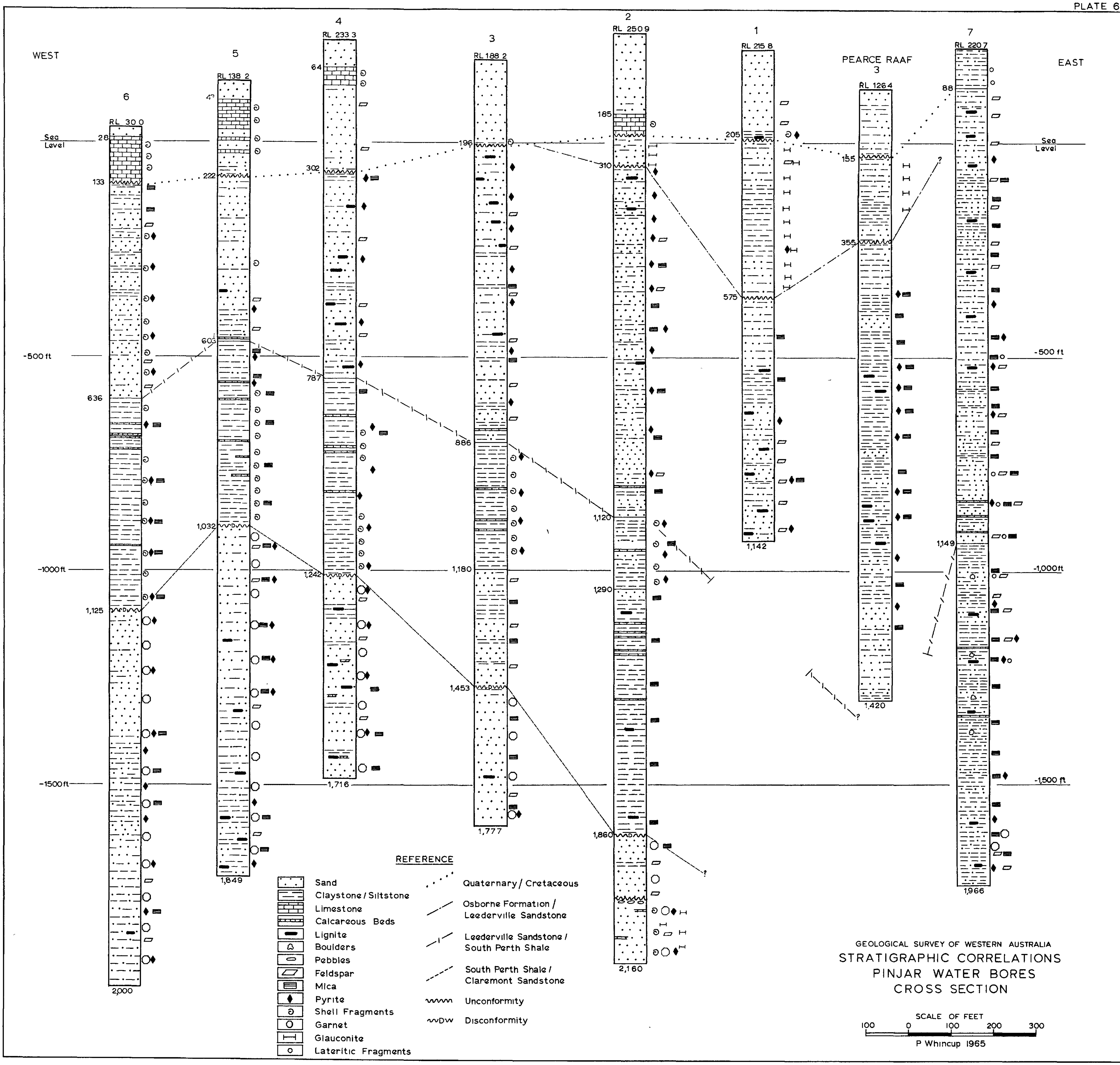
The Claremont Sandstone aquifer was tested in the four westernmost bores and the piezometric surface (Plate No. 8) shows a gentle fall to the west. With additional information available from Metropolitan artesian bores, contours on top of the piezometric surface can be drawn between Pinjar and Perth (Plate No. 8). The isopiestic lines indicate intake from a general direction northeast of Bore No. 1 but the nature of the intake cannot be conjectured. Exposure of the Claremont Sandstone seems unlikely and the intake may be from a fault zone.

QUALITY OF THE UNDERGROUND WATER

Quaternary

A graphical representation of salinities in the Lower Cretaceous and Upper Jurassic aquifers is shown on Plate No. 9. Domestic quality water is found in the Quaternary aquifer over the whole area, the groundwater from limestone terrain being very hard. Near the coast the water has a higher

PLATE 6

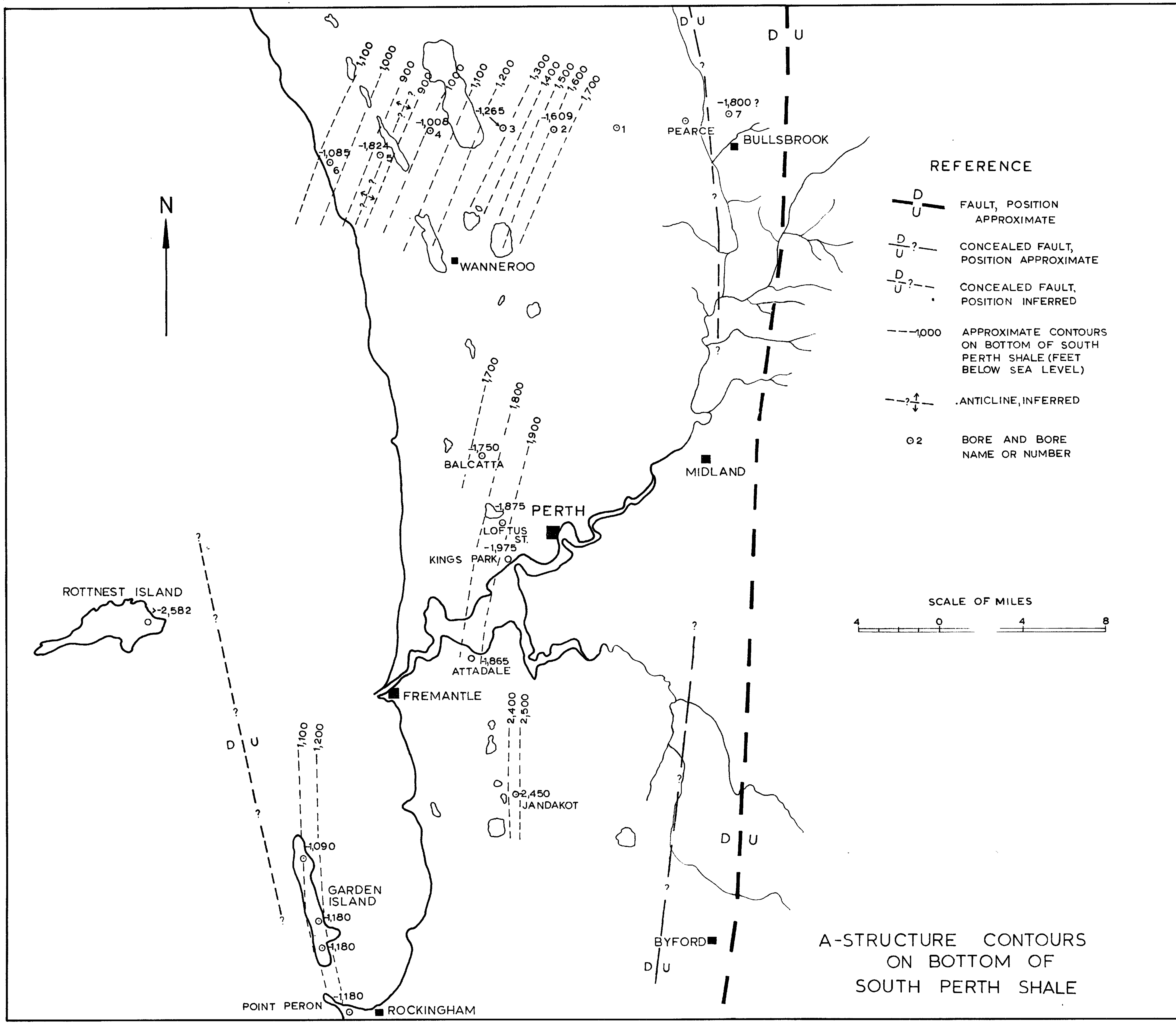

WEST
EAST
6
5
4
3
2
1
PEARCE RAAF 3
7
RL 30 0
RL 138 2
RL 233 3
RL 188 2
RL 250 9
RL 215 8
RL 126 4
RL 220 7
Sea Level
-500 ft
-1000 ft
-1500 ft
28
133
636
1,125
2,000
222
603
1,032
1,849
64
302
787
1,242
1,716
196
886
1,180
1,453
1,777
185
310
1,120
1,290
1,860
2,160
205
575
1,142
155
355
1,420
88
1,149
1,966
REFERENCE
Sand
Claystone / Siltstone
Limestone
Calcareous Beds
Lignite
Boulders
Pebbles
Feldspar
Mica
Pyrite
Shell Fragments
Garnet
Glauconite
Lateritic Fragments
Quaternary / Cretaceous
Osborne Formation / Leederville Sandstone
Leederville Sandstone / South Perth Shale
South Perth Shale / Claremont Sandstone
Unconformity
Disconformity
GEOLOGICAL SURVEY OF WESTERN AUSTRALIA
STRATIGRAPHIC CORRELATIONS
PINJAR WATER BORES
CROSS SECTION
SCALE OF FEET
100 0 100 200 300
P Whincup 1965

8902

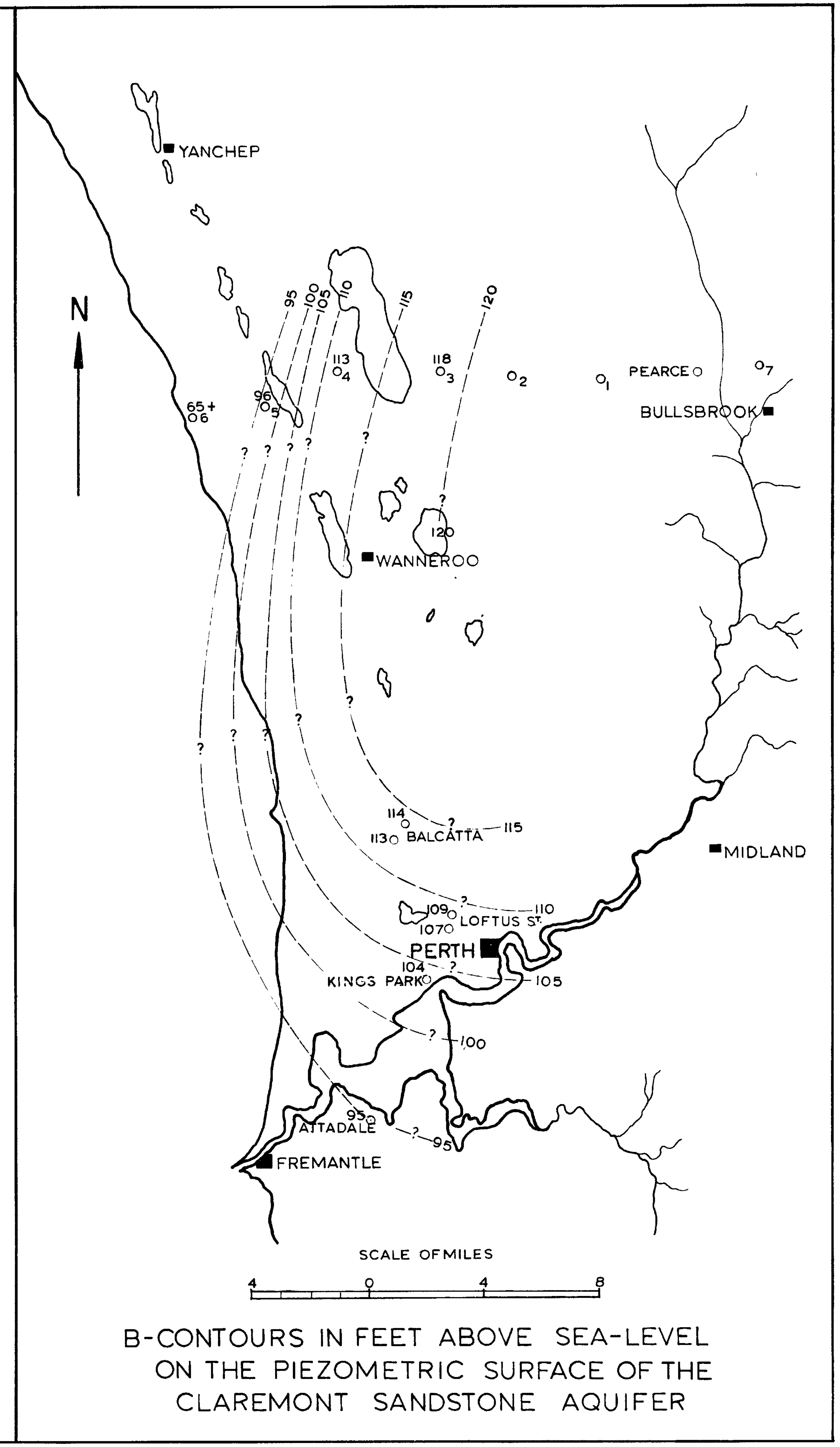
HYDRAULIC SURFACES PINJAR CROSS SECTION

GEOLOGICAL SECTION ACROSS PERTH BASIN AT PINJAR

9250



A-STRUCTURE CONTOURS ON BOTTOM OF SOUTH PERTH SHALE



B-CONTOURS IN FEET ABOVE SEA-LEVEL ON THE PIEZOMETRIC SURFACE OF THE CLAREMONT SANDSTONE AQUIFER

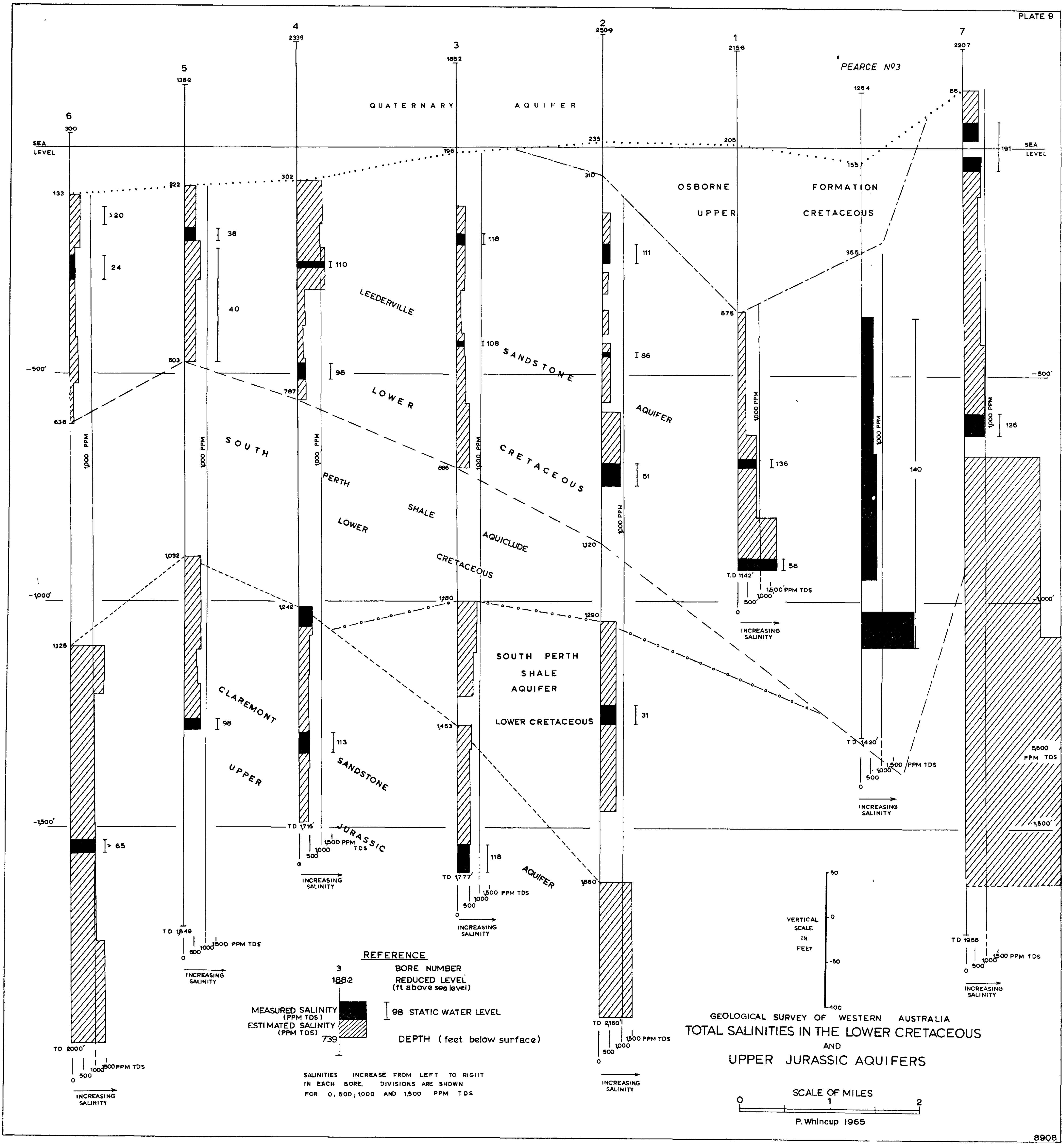


PLATE 9
6
300
5
138·2
4
233·9
3
188·2
2
250·9
1
215·8
PEARCE Nº3
126·4
7
220·7
QUATERNARY AQUIFER
SEA LEVEL
OSBORNE FORMATION
UPPER CRETACEOUS
LEEDERVILLE SANDSTONE AQUIFER
LOWER CRETACEOUS
SOUTH PERTH SHALE AQUICLUDE
LOWER CRETACEOUS
SOUTH PERTH SHALE AQUIFER
LOWER CRETACEOUS
CLAREMONT SANDSTONE AQUIFER
UPPER JURASSIC
-500'
-1,000'
-1,500'
1,000 PPM
0
500
1,000
1,500 PPM TDS
INCREASING SALINITY
TD 2000'
TD 1849
TD 1716'
TD 1,777'
TD 2,160'
TD 1142'
TD 1420'
TD 1958
5,800 PPM TDS
VERTICAL SCALE IN FEET
REFERENCE
3
188·2
BORE NUMBER
REDUCED LEVEL (ft above sea level)
MEASURED SALINITY (PPM TDS)
ESTIMATED SALINITY (PPM TDS)
739
98 STATIC WATER LEVEL
DEPTH (feet below surface)
SALINITIES INCREASE FROM LEFT TO RIGHT IN EACH BORE. DIVISIONS ARE SHOWN FOR 0, 500, 1,000 AND 1,500 PPM TDS
GEOLOGICAL SURVEY OF WESTERN AUSTRALIA
TOTAL SALINITIES IN THE LOWER CRETACEOUS AND UPPER JURASSIC AQUIFERS
SCALE OF MILES
0
1
2
P. Whincup 1965
8908

than normal salinity as a result of sea water contamination. Adjacent to lakes the groundwater may be contaminated as the lakes become brackish towards the end of summer. The effect will be greatest on the southwestern side of lakes in the direction of groundwater movement.

Upper Cretaceous

Water in the upper part of the Osborne Formation aquifer is of domestic quality, but salinities are higher than in the Quaternary aquifer. The water is very soft because of the glauconitic nature of the sands.

Lower Cretaceous

The *Leederville Sandstone* aquifer yielded domestic quality water in all bores. In the eastern bores the quality deteriorates rapidly with depth, resulting from a downward decrease in permeability. The beds become less clayey away from the scarp and, towards the coast, the downward increase in salinity is negligible.

Normally the concentration of total salts increases with distance from the intake area, but in the Pinjar area leakage of good quality water from the Quaternary aquifer is responsible for an improvement in quality west of Bore No. 2. A salinity of about 1,100 ppm T.D.S. in the upper part of the aquifer in Bore No. 4 is of interest. This bore is directly west of Lake Pinjar and the southwest movement of the shallow groundwater has introduced brackish water from the lake into the Leederville Sandstone aquifer.

The chemical character of groundwater is, to a large extent, determined in the topsoil and zone of rock decomposition and is thus dependent on rock types in the intake area. Variations in chemical quality of the water in the Pinjar area are indicative of intake from two different terrains, limestone in the west and granite in the east.

The *South Perth Shale* aquifer contains domestic quality water in the centre of the basin. Near the scarp it contains saline water.

Upper Jurassic

In Bores No. 3, 4 and 5 the Claremont Sandstone contains domestic quality water. To the east and west of these bores the quality deteriorates to about 1,500 ppm T.D.S. Structural and hence hydrological conditions in Bore No. 2 are not typical and may not extend towards the east.

In Bore No. 6 an increase in salinity which occurred below about 1,800 feet was also noted in the Metropolitan area in the Balcatta No. 2 Bore.

The chemical qualities of water from the Claremont Sandstone aquifer in the Perth and Pinjar areas are remarkably similar, suggesting that the aquifer is continuous between the two areas. A comparison of the Ca/Mg ratios shows a slight but definite decrease in the ratio southwards from Bore No. 6 to the Attadale bore, in a southern district of the Metropolitan area. A decreasing Ca/Mg ratio is a reflection on the distance travelled through the aquifer and in this instance suggests a southerly movement of the groundwater with intake north of Pinjar.

CONCLUSIONS

The drilling programme has provided much new information on the stratigraphy and hydrology of the Cretaceous and Jurassic sediments in this part of the Perth Basin. Upper Cretaceous sediments, which occur only in the eastern half of the basin, are flat-lying and do not possess good aquifer properties.

The Lower Cretaceous and Upper Jurassic sediments have a gentle dip to the southeast with a reversal to the northwest near the coast. At depth below Bore No. 2, erosion in Upper Jurassic times may have resulted in the incursion of marine sediments along a northeast-trending channel. Near the Darling Scarp post-Cretaceous movements have uplifted the sediments about 500 feet to the east.

Domestic quality water was proved in the Leederville Sandstone, South Perth Shale, and Claremont Sandstone aquifers. The Leederville Sandstone aquifer occurs at depths of between 88 and 575 feet below the surface and towards the east has a thickness of more than 1,000 feet. It yielded domestic quality water in all bores; west of surface lakes such as Lake Pinjar the water is brackish in the upper part of the aquifer and in the easterly bores the quality deteriorates rapidly with depth. The static head of the aquifer drops from 191 feet above sea level on the scarp to 24 feet above sea level at the coast.

The South Perth Shale aquifer occurs at a depth of about 1,200 feet and contains domestic quality water in the centre of the area.

The Claremont Sandstone aquifer was intersected at depths of between 1,032 and 1,860 feet below the surface. It was not fully penetrated, the maximum thickness drilled being 875 feet near the coast. Inland the aquifer contains domestic quality water but in the coastal bore the salinity is too high for domestic purposes. The water in Bore No. 2 is saline, probably as a result of structural complications which may not extend towards the east. An increase in salinity was noted in Bore No. 6 and also in the Balcatta bores at a penetration of about 600 feet into the aquifer. The static head falls from 118 feet above sea level in the east to 70 feet above sea level in the west. The aquifer is considered to extend southwards to the Perth Metropolitan area and is expected to yield domestic water at least as far south as Balcatta, the static head being approximately 100 to 120 feet above sea level.

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GROUNDWATER FROM GRANITIC ROCKS, MOOLYELLA CREEK AREA, NEAR MARBLE BAR, NORTH-WEST DIVISION

by A. D. Allen

ABSTRACT

The Moolyella Creek area in the Pilbara Groundwater Province, is underlain by jointed, gneissic granite intruded by quartz veins and pegmatites, of the Archaean Talga—Mt. Edgar batholith.

More than 30 bores with a total footage exceeding 2,000 feet were drilled by a down-hole-hammer rig in an area of about 50 square miles. An extensive body of pressure water was encountered beneath dense clays which have formed by weathering in situ of the granitic rocks. Groundwater from joints, quartz veins and pegmatites ranged in salinity between 460 and 770 ppm T.D.S. and had a temperature of 87.5°F (31.0°C). Approximate bore yields ranged from seepages to 3,500 gph. One bore in every two or three drilled to over 60 feet had a reported yield of 1,000 gph or more. Large quartz veins are considered very good potential sites. Sporadic recharge occurs through joints, and in areas immediately surrounding granitic hills; elsewhere the weathered granite precludes recharge. Water levels may fluctuate quite widely with variations in rainfall. Good quality groundwater is generally available provided bores are drilled deep enough and some failure bores are anticipated.

INTRODUCTION

Location

The Moolyella Creek area is in the Pilbara Gold Field on the divide between Brockman Creek and Talga River (tributaries of the De Grey River). The nearest town is Marble Bar, 15 miles to the southwest on the Great Northern Highway.

Climate and Vegetation

The climate is typified by cool dry winters and hot summers, with an unreliable summer rainfall. The average annual rainfall for Marble Bar is 13.41 inches, but this has varied between 2.80 inches and 29.20 inches. The rain usually falls in heavy downpours from thunderstorms or cyclones. Annual evaporation is greater than 110 inches and exceeds the average annual rainfall by 9 or 10 times.

The vegetation is mainly spinifex and small shrubs, with a few trees along the drainage lines.

Physiography

The area is on a dissected divide between Brockman Creek and Talga River, the highest part being about 250 feet above river level and characterised by bare, rounded, exfoliated and jointed hills and isolated bosses of granitic rocks, drained by small, relatively flat, alluvial valleys. Except for a few prominent ridges formed by quartz veins, the rest of the area slopes gently towards the main drainages.

Drilling Programme

Concentrations of alluvial and eluvial cassiterite were first found in the Moolyella area in 1899. Since that time there has been sporadic production, but mining activity has been restricted by the lack of water. Improved prices for tin have led to renewed mining in the area in recent years.

In 1962 at the request of Mineral Concentrates Pty. Ltd., MacLeod (1962) made an inspection of the Moolyella Creek Area and recommended some bore sites. A number of bores were drilled and two were successful (Bores A and B).

The area subsequently became the property of Pilbara Tin Co. (Kathleen Investments Ltd.) and a programme of large-scale mining began. Allen (1964) inspected the area and recommended 15 bore sites. In mid-1965 more than 34 bores with a total footage of over 2,000 feet were drilled in an area of about 50 square miles. Some were on sites recommended by geologists and others on sites selected by company personnel. The bores tested most of the promising topographic and geological situations for groundwater. The drilling was done by Geophysical Services International Pty. Ltd. (G.S.I.) using a Mayhew-1000 rotary rig with a

Table 1

MOOLYELLA CREEK AREA: SUMMARY OF GROUNDWATER DATA

Bore No.	Depth (feet)	Water cut (feet below surface)	Static Water Level (feet below surface)	Salinity p.p.m. TDS	Supply (g.p.h.) (approx.)	Thickness of weathered granite (feet)	Remarks
A	100	27′ and 100′	12	good	2,500	98	R.L. Collar 55·57′
B	60	58′ 6″	20	460	1,500	60	R.L. Collar 66·59′
C	33	....	23	good	good	....	
D	No data.						
1	63	54	24′ 2″	....	300	30	
2	75	66	....	....	small	10	Dry at 75′
3	70	45	....	....	200	? 16	
4	60	25	24′ 0″	480	2,000	5	R.L. Collar 23·26′
5	70	....	....	....	Reputed dry	47	Contained water 18/8/65
6	80	20	....	....	small	60	
7	84	30′ and 50′	24′ 0″	....	1,000	54	R.L. Collar 16·48′
8	70	28′ and 50′	24′ 3″	....	3,500	54	R.L. Collar 17·10′
9	66	40	26′ 0″	....	1,000	29	R.L. Collar 30·06′
10	66	....	....	....	400	20	
11	54	....	....	....	Reputed dry	40	Contained water 18/8/65
12	40	....	....	....	do.	16	do. do.
13	45	....	....	....	do.	33	do. do.
14	39	14	....	....	1,200	14	
15	50	....	....	....	Reputed dry	15	Contained water 18/8/65
16	45	....	....	....	do.	15	do. do.
17	45	....	....	....	do.	15	do. do.
18	60	....	....	....	do.	18	do. do.
19	70	....	....	770	1,200	70	
20	60	30	23′ 9″	....	1,200	39	R.L. Collar 49·12′
21	54	35	....	....	2,000	30	R.L. Collar 62·79′
22	79	38	....	....	2,000	30	Basic lens 50·50′
23	63	35	....	....	Small supply	? 22	
24	35	....	....	....	(?)	30	Hole caved, ? no water
25	63	30	....	....	150	30	
26	99	....	....	....	Small supply	30	Deepened from 69′
27	54	....	....	....	Reputed dry	23	Contained water 18/8/65
28	70	40	....	....	100	40	
29	63	41	19′ 9″	700	2,500	44	R.L. Collar 17·18′
30	81	31′ and 71′	21′ 9″	....	2,000	31	R.L. Collar 17·34′
31	105	18	63	....	250	5	Doubtful water data
32	114	....	? 56	....	100	60	do. do.
33	65	32′ and 48′	30′ 1″	....	2,500	35	R.L. Collar 66·62′
34	69	40	33′ 9″	....	2,500	43	R.L. Collar 66·59′

down-hole-hammer attachment. No particular drilling problems were encountered apart from limited 'caving' of some weathered rock.

Plate 10 shows the approximate position of most of the bore sites, and Table 1 is a summary of available drilling results.

GEOLOGY

The Moolyella Creek area is on the Pilbara Block (Ryan, 1965) and is shown on the Marble Bar 4-mile Geological Sheet. The geology of the Sheet area has been described by Noldart and Wyatt (1962).

The area lies towards the western edge of the Talga—Mt. Edgar batholith which intrudes basic volcanics, cherts, quartzites and dolomites of the Warrawoona succession. According to Noldart and Wyatt the batholith is composed of a central core of homogeneous 'granite' grading outwards through an intermediate zone of gneissic rocks, which is extensively intruded by pegmatites and quartz veins, to a fringe of granitized sedimentary and volcanic rocks.

The Moolyella Creek area lies completely within the gneissic zone, which mainly consists of medium to coarse-grained adamellites (quartz monzonites). The granitic rocks are occasionally porphyritic and composed principally of quartz, microcline and oligoclase, with minor biotite and muscovite, and accessory apatite, sphene, fluorite and zircon. Garnet occurs in some pegmatites.

The granites are well jointed. Larger master joints have tended to be the focus for drainage and consequently usually underlie the small alluvial valleys around the hills. Smaller joints and exfoliation joints are common.

The small alluvial valleys leading from the hills contain alluvium and eluvium, up to 30 feet thick but usually considerably less. The alluvium and eluvium result from mechanical erosion and appear to have been deposited during a period of aggradation. The drainage lines are wide and ill defined except in the larger creeks where a well defined bed may be present. The main deposits of cassiterite occur in the upper reaches of the drainage lines.

In the areas of low relief where there is little active mechanical erosion, the granites have undergone chemical weathering in situ, and the component minerals have been altered to a sandy clay ("rotten" or "decomposed" granite) which grades downward into fresh granite. In the drillers' logs there is no distinction between alluvium and weathered granite, so that the true thickness is uncertain. Judging from the logs the weathered zone ranges in thickness between 5 feet and 70 feet, averaging about 30 feet. The depth of weathering appears to be greatest below the poorly defined drainage lines, but this is uncertain. The size and frequency of jointing, and number of quartz veins and pegmatites is probably a more important factor affecting depth of weathering. That the weathered granite is impermeable near the surface and permeable at depth probably reflects a collapse and subsequent blockage of the joint system as weathering progresses, perhaps also with disruption of the potential water-bearing conduits by soil creep.

HYDROGEOLOGY

A map published in the Review of Australia's Water Resources (1963) shows the area to be underlain by fractured rocks in which there is insufficient data to delimit areas of different quality water. However, domestic and stock quality waters are known to occur.

Occurrence of Groundwater

Pressure water, usually confined beneath a layer of dense, clayey, weathered granite, was found in all bores drilled to more than 35 feet in depth. Although some bores were reported by the drillers as being dry, later inspection showed that they had filled with groundwater which had seeped slowly into the holes.

The groundwater was first encountered at depths between 14 feet and 38 feet below the surface, and at an average depth of 35 feet. It is reported to have risen between 1 foot and 38 feet in different bores, depending on (1) the elevation of the site; (2) the degree of weathering; (3) the depth of water-bearing joints etc.; and (4) whether seepage was detected by the drillers. The water rest levels ranged between about 20 feet and 35 feet below the surface depending on the elevation of the site.

Water occurred in both weathered and fresh granite. In the former it was obtained from relict joints, and particularly from weathered quartz veins and pegmatites. Apparently quartz veins and pegmatites are sufficiently fractured, contain interconnected vugs, or become open or fractured during weathering and changes in volume of the host rock.

In the unweathered granite, water was obtained from primary joints, exfoliation joints, quartz veins, and in the case of bores no. 4, 30, 32, and 34, from weathered pegmatites enclosed in the fresh granite.

Plate 10 shows the piezometric surface to have a gradient of about 10 feet per mile from a high central area of outcropping granite at the headwaters of Moolyella, Huntsman and Six-Mile Creeks, downward towards Brockman Creek and Talga River. Evidently there is an extensive body of groundwater occurring within interconnected joints etc. throughout the area (Allen, 1964).

Groundwater Quality

The salinity is known to range between 460 and 770 ppm total dissolved solids and is suitable for domestic purposes. In Bore A the groundwater temperature was 87.5°F (31.0°C) and the groundwater is probably at about this temperature throughout the area.

Standard analyses for three samples are given in Table 2; and the concentrations of the principal ions are plotted in milli-equivalents on a semi-logarithmic graph in Figure 7. The samples have a broad similarity in composition but the ratios of various ions, Ca/Mg or Mg/Na for example, may vary widely. The variations possibly reflect the relative ages of the water or degree of weathering of the immediate aquifer, rather than differences in composition of the aquifer.

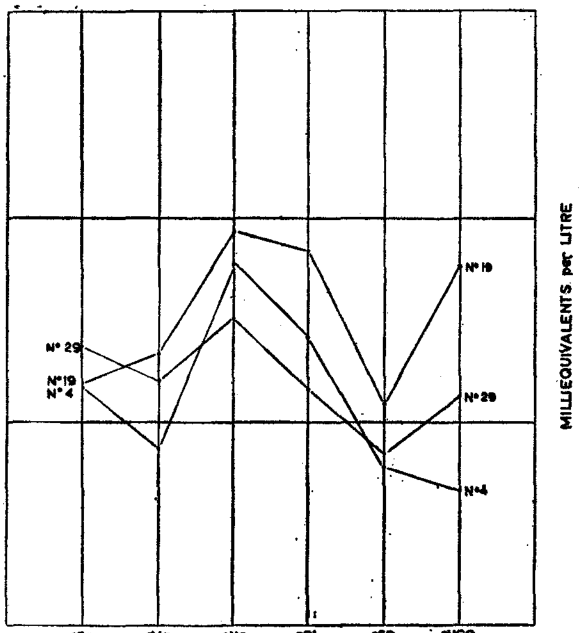

FIGURE 7 : MOOLYELLA CREEK AREA

SEMI LOGARITHMIC GRAPH

OF

AVAILABLE GROUNDWATER ANALYSES

Table 2

MOOLYELLA CREEK AREA: STANDARD ANALYSES OF GROUNDWATER FROM THREE BORES

NAME	No. 19	No. 4	No. 29
Sample No.	11142	11143	11144
Specific Conductivity 20° C. Micromhos	1200	710	1000
Appearance	Clear with grey deposit	Clear with slight grey deposit	Clear with slight brown deposit
Colour	Colourless	Colourless	Colourless
Odour	Earthy	Nil	Nil
pH	7·1	7·2	7·3
MINERAL MATTER			
Calcium Ca	62	29	47
Magnesium Mg	26	9	19
Sodium Na	200	134	172
Potassium K	3	2	2
Bicarbonate HCO_3	357	285	383
Carbonate CO_3	Nil	Nil	Nil
Sulphate SO_4	58	29	34
Chloride Cl	247	95	151
Nitrate NO_3	n.d.	n.d.	n.d.
Silica SiO_2	41	28	37
Iron Fe	0·6	0·1	1·0
Total by conductivity	840	500	700
Total by evaporation	770	480	670
HARDNESS (Calculated as ppm $CaCO_3$)			
Total hardness	262	109	195
Bicarbonate hardness	262	109	195
Non-carbonate hardness	Nil	Nil	Nil
Calcium hardness	155	72	117
Magnesium hardness	107	37	78

The groundwater salinity is particularly low in comparison with water from areas of similar granitic rocks and rainfall in the South-West Shield (Groundwater) Province (Mackay, 1963). The main difference between the provinces arises from the fact that the Pilbara Province has a well integrated drainage system, whereas the drainage system of the South-West Shield Province is ill-defined and unco-ordinated. In a poorly integrated drainage system, groundwater containing salts derived from rock weathering cannot be discharged into drainage lines and removed from the area. Instead, the groundwater is concentrated by evaporation and evapotranspiration and extensive bodies of saline water build up with localized patches of good quality water near intakes.

YIELDS OF BORES

Bore yields (Table 1) were not tested accurately. Approximate yields were estimated from the amount of water lifted by blowing air from a compressor, through the drill-bit, which had been lifted a small distance from the bottom of the hole.

Thirteen bores, or slightly less than one third of the total drilled, are reported to yield 1,000 gph to 3,500 gph; six yielded 100 gph or more and fifteen gave very small supplies or were reported as dry.

The drilling results indicate that the deeper the bore the greater is the likelihood of encountering a supply of over 1,000 gph, and that about one bore in every two or three drilled deeper than 60 feet is likely to yield 1,000 gph or more. The optimum depth for bores in the area is uncertain. Probably the largest supplies are obtainable between 60 feet and 150 feet. Below 150 feet only the larger joints are open; and nearer the surface the degree of weathering indicates that in some localities at least, water can percolate freely in well jointed rocks to depths of at least 70 feet.

Water bearing joints occupy less than 1% of the whole volume of rock, so that the volume of water available is limited. Bores A and B are together reported to yield about 70,000 gallons per day or about 10 million gallons per year, during operations. The drawdowns of the pumping bores are not known but it is likely that there is some mutual interference between pumping bores, with a resulting decline in water levels.

Because the groundwater is held in fractured rock, it is able to move more rapidly than water held in most porous rocks. Where there are large numbers of interconnected conduits, the best sites for bores are the master joints, faults or large quartz veins which may extend over a long distance. In the Moolyella Creek area a prominent quartz vein strikes northeast across the area, approximately at right angles to the direction of groundwater movement.

The vein and the country rock are extensively jointed at the surface and if the joints are not infilled with clay or secondary minerals the vein is probably highly permeable. A bore drilled on the vein should have good prospects. As far as can be determined, no bores are sited on the vein but Bore 33, Bore 22, Bore A and Bore 19, all nearby, have yields of over 1,000 gph.

Intake

The gradient of the piezometric surface and the fluctuations in water levels indicate that intake is direct from rainfall in the highest areas of exposed granitic rocks. Joints, sandy areas directly surrounding the granitic outcrops, and the upper reaches of some of the drainages are probably the main intakes. Elsewhere the clays which confine the pressure water prevent downward percolation.

Because of the irregular rainfall, intake must be sporadic, and the amount of groundwater probably fluctuates quite widely from year to year. This is borne out by observations of water levels which are reported to decline by 5 to 10 feet during dry seasons and to recover rapidly after rainfall.

CONCLUSIONS

The area is considered to have low to moderate groundwater potential, but whether the same conditions occur throughout the batholith is uncertain. Pressure water should be generally available. The best bore sites are probably on large quartz veins, and the best prospects for obtaining a supply of over 1,000 gph are from bores 60 feet to 150 feet deep.

Along drainage lines, bores can be drilled by cable tool plants with a moderate chance of success. However it is unlikely that they can be drilled to the optimum depth, and down-hole-hammer or rotary plants are more suitable. The necessity to ream if casing is to be inserted, and the testing of the supply by air blowing, are unsatisfactory features of these plants.

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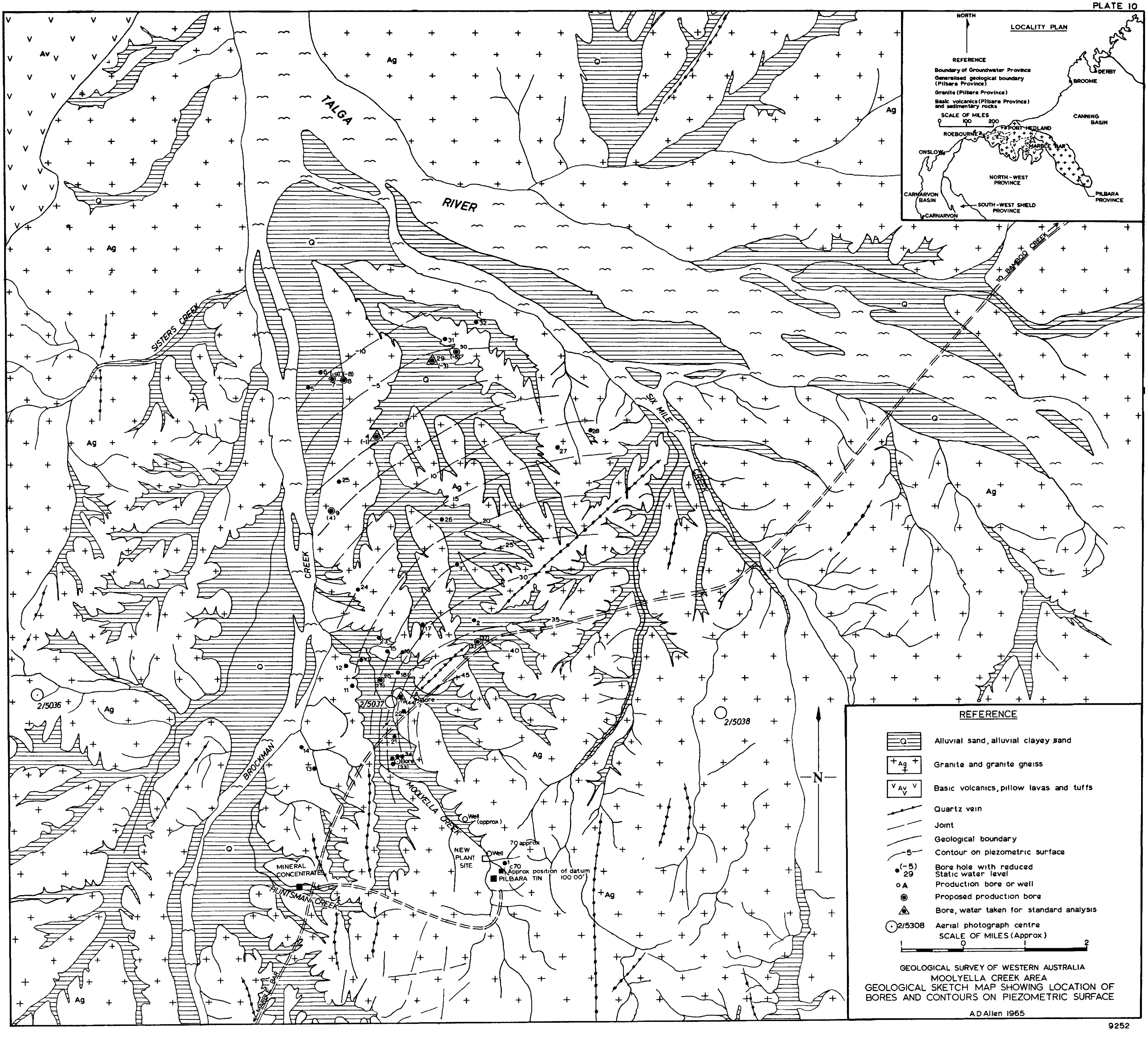
LOCALITY PLAN
NORTH
REFERENCE
Boundary of Groundwater Province
Generalised geological boundary (Pilbara Province)
Granite (Pilbara Province)
Basic volcanics (Pilbara Province) and sedimentary rocks
SCALE OF MILES
0 100 200
DERBY
BROOME
CANNING BASIN
PORT HEDLAND
ROEBOURNE
MARBLE BAR
ONSLOW
NORTH-WEST PROVINCE
CARNARVON BASIN
CARNARVON
SOUTH-WEST SHIELD PROVINCE
PILBARA PROVINCE
TALGA
RIVER
SISTERS CREEK
BROCKMAN
CREEK
SIX MILE
CREEK
TO BAMBOO CREEK
MOOLYELLA CREEK
HUNTSMAN CREEK
MARBLE BAR
MINERAL CONCENTRATES
NEW PLANT SITE
Well (approx)
Well
70 approx
c70
Approx position of datum 100 00'
PILBARA TIN
Bore
2/5036
2/5037
2/5038
REFERENCE
Alluvial sand, alluvial clayey sand
Granite and granite gneiss
Basic volcanics, pillow lavas and tuffs
Quartz vein
Joint
Geological boundary
Contour on piezometric surface
Bore hole with reduced Static water level
Production bore or well
Proposed production bore
Bore, water taken for standard analysis
Aerial photograph centre
SCALE OF MILES (Approx)
1 0 2
GEOLOGICAL SURVEY OF WESTERN AUSTRALIA
MOOLYELLA CREEK AREA
GEOLOGICAL SKETCH MAP SHOWING LOCATION OF BORES AND CONTOURS ON PIEZOMETRIC SURFACE
A D Allen 1965
9252

AN APPRAISAL OF GROUNDWATER SOURCES IN THE RAVENSTHORPE DISTRICT

By D. H. Probert

INTRODUCTION

At the request of the Public Works Department a geological reconnaissance of the Ravensthorpe District was made between 27th August and 9th September, 1965, as a supply of 4,000 gallons per hour of potable groundwater was needed for the Ravensthorpe Town Supply.

The search covered an area of about 1,200 square miles centred on Ravensthorpe, bounded approximately by the West River, Lake Chidnup, the No. 1 Rabbit Proof Fence, and the Jerdacuttup area.

The Ravensthorpe District has an average rainfall between 14 and 16 inches per year, falling mainly in winter, although summer thunderstorms contribute good runoff for catchment purposes. The present town supply is obtained from bitumen catchment dams and from household tanks. Stock supplies in periods of water shortage are carted up to 20 miles.

PHYSIOGRAPHY AND GEOLOGY

The geology and physiography of the Ravensthorpe Area have been described in detail by Sofoulis (1958), who divided the area into three divisions within Jutson's Salinaland.

The *Hinterland Division* lies north of a line extending roughly east-west from Mt. Short. It is undulating sand plain characterised by bare granitic hills rising 250 feet above the general plateau level of 1,000 to 1,500 feet, and having a low rainfall, poorly developed internal drainage, alluvium filled valleys, and salt lakes.

The *Intermediate Division* lies to the south of the hinterland and has an elevation of between 400 and 800 feet, decreasing steadily to the southeast. The Ravensthorpe Range and the Barren Range belts form the most striking topographic features, with elevations of a few hundred feet to over 1,000 feet above the general level. A well developed consequent drainage system dissects the area and includes the West, Phillips, Steere, and Jerdacuttup Rivers, which have alluvium filled valleys varying in development from early to late maturity. The rivers also have meandering and braided channels and flow only after heavy rain.

The *Coastal Division* is a narrow strip mainly within 4 miles of the coast, having a maximum elevation of approximately 250 feet and characterised by a rocky coast, sandy beaches, dunes, and Coastal Limestone. The major drainages are barred and the shorter streams from the Barren Range are deeply entrenched.

Two age groups of rocks, Tertiary-Recent and Precambrian, occur in the area and have been described in detail by Sofoulis. The distribution of these rocks is shown on the accompanying geological plan (Plate 11). Broadly they are:

Recent-Late Tertiary	Cap rocks, alluvials, eolian sands and Coastal Limestone.	
Tertiary	.... *Plantagenet Beds*—clay, siltstone, spongolite.	
Proterozoic	.... *Mt. Barren Series*—metamorphosed sedimentary rocks.	
Late Archaean	.... Granite and ore emplacement.	
Archaean	*Whitestone Phase* / *Greenstone Phase*	Metamorphosed sediments, intrusive ultrabasic and basic rocks
	Basement granitic complex.	

The *Archaean basement complex* is the dominant rock type north, west, and east of Ravensthorpe, and consists of granite and gneiss intersected by quartz and pegmatite veins. Typically the rocks are foliated and contain gneissic bands.

The *Archaean rocks* form a highly folded geosynclinal remnant within the granitic basement and can be subdivided into Whitestone and Greenstone phases of the Ravensthorpe System. The Whitestone phase, forming the crest of the Ravensthorpe Range, consists of metasedimentary schists, minor jaspilites, and manganiferous and dolomitic horizons; it grades into the Greenstone phase, which is a sequence of metamorphosed, partly serpentinized, intrustive or extrusive, ultrabasic and basic lavas, and pyroclastics, underlain by phyllites and quartzites. The geosynclinal structure extends irregularly from 12 miles north of Ravensthorpe to 4 to 5 miles south of Kundip and its greatest width is about 25 miles.

Late Archaean granodiorite intrudes the geosynclinal rocks and outcrops over an area of some 200 square miles southwest of Ravensthorpe. The granite contains partly digested sedimentary remnants of quartzitic and basic nature and is intruded by quartz dolerite dykes and pegmatite veins.

The *Proterozoic Mt. Barren Series* underlies the area south and west of Kundip and extends westward towards the Stirling Ranges. These sedimentary rocks are only slightly metamorphosed and moderately folded and consist of alternating, interbedded quartzite, phyllitic and micaceous schist, shale, grit, sandstone, dolomite, and conglomerate.

Tertiary Plantagenet Beds consisting of silty, sandy and clayey sediments are thinly and irregularly distributed over the Precambrian rocks within and slightly north of the coastal area. Their maximum development was noted by Sofoulis (1958) in the principal drainage valleys, e.g. 250 feet of spongolite near the Fitzgerald River. Mostly however, they do not exceed 100 feet in thickness.

Tertiary-Recent sediments consist of eolian and residual sands, alluvium and various cap rocks which occur throughout the district. These include kaolinitic, calcareous, siliceous, magnesitic, and lateritic types which commonly reflect the underlying rock types, e.g. magnesite over ultrabasic rocks. The cappings and alluvium are generally thin, although Coastal Limestone is over 100 feet thick near the coast. Laterites are well developed over the Ravensthorpe Range and other higher terrain, and they also are present, though generally not as well developed, in some of the lower drainage channels and depressions.

HYDROGEOLOGY

Since prospecting commenced in 1892 the greenstones have been drilled in the search for minerals, but little information is available regarding the results. The few water bores have been mostly in these rocks and associated alluvials because they form the richest agricultural soils of the district; although a few drill holes and several wells have also been sunk in granite areas.

The Archaean Whitestone and Greenstone phases are unlikely sources of usable groundwater. All reported drill holes and mine workings in the greenstones have produced saline groundwater at depths of 20 to 80 feet; e.g. at the Elverdton Mine 90,000 gallons/day of 13,300 ppm dissolved salts obtained between 40 and 80 feet. Surface water flows are intermittent and creeks contain usable stock water only in periods of high flow. The Whitestone phase outcropping at the crest of the Ravensthorpe Range shows similar characteristics. Although no drilling has been reported, creeks at the crest of the range were saline after a period of good rainfall and consequently the underlying groundwater is also probably saline.

The granite and granitic gneiss outcrop extensively, though often covered by thin veneers of sand, laterite, and weathering products. Only one small supply of groundwater has been tapped in the granite by wells at Cocanarup, west-southwest of Ravensthorpe, and this is of domestic quality though of limited intermittent supply. Springs formed by hillside seepage along prominent joints in creek beds are the main supply for stock in periods of drought. These occur at Carlingup, Woodenup, Cocanarup Springs, Manyatup, and Moolyall Rocks. The water is of very good stock quality containing 1,500 to 3,000 parts per million of dissolved salts. Little drilling has been done in the granite areas, which have only recently been opened up for farming. As more land is cleared it is quite likely that small supplies of stock and domestic groundwater will be obtained in the area but not in the quantity required for town usage.

The rocks of the Mt. Barren Series were also examined as a possible source of groundwater. West of Kundip, moderately dipping beds of quartzite and phyllite abut outcropping granite which forms a natural watershed to the south. The phyllitic beds are micaceous, weathered, and appear to be relatively impervious. The quartzites, which generally outcrop as hills, are fresh, and are intersected by two sets of joints, parallel and at right angles to the bedding, at spacings varying from 1 to 12 inches. They may provide a source of groundwater but, because of their location and of the fact that the run-off from the granitic areas varies in salinity (500 to 2,000 ppm), only irregular supplies of stock or irrigation quality water would be expected.

Alluvial deposits occur in the major stream valleys or as small outwash deposits in the granite terrain. Drilling within the larger alluvial flats has yielded either stock or saline water, the quality of which varies with the salinity of the stream flow and is only usable for a short period of the year. In the smaller, higher-level alluvial deposits, good quality water has been encountered, but this is of uncertain quantity and dries up in the periods of dry weather.

Stock water has been found in probable Plantagenet Beds in the Jerdacuttup area southeast of Ravensthorpe, but this area has not been fully developed and few water bores have been drilled. Most yielded saline water, and only stock quality water is expected.

CONCLUSIONS AND RECOMMENDATIONS.

No sources of underground water suitable for the Ravensthorpe town supply are believed to exist within a 15 to 20 mile radius of the town. Small supplies of stock and domestic quality groundwater should be obtainable at some sites in the granitic areas, particularly when more land is cleared; and stock water supplies are also probably available in certain areas within the Plantagenet Beds and Mt. Barren Series south of Ravensthorpe. They do not represent a satisfactory source of water for the township.

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EROSION OF THE BYWASH SPILLWAY AT SERPENTINE DAM

by F. R. Gordon

ABSTRACT

At the Serpentine Dam 40 miles southeast of Perth, the first discharge of water down the spillway caused erosion and damage to parts of the unlined bywash channel. Most of the spillway is excavated in a medium to coarse-grained porphyritic granite gneiss which is cut by dolerite dykes from 9 inches to 40 feet wide striking across the bywash channel.

All the problems concerning the erosion and stability of the spillway result from the presence of well developed and extensive sheet joints subparallel to the natural rock surface. As the channel has been cut along the steep valley side and the sheet joints dip towards the bottom of the valley, large rock and debris masses are poised on the uphill side of the cut at angles that in some cases would permit block glide into the bywash channel. The most serious result of such a fall would be to divert the water flow against an easily eroded part of the downhill wall. Scour grooving, and accelerated erosion of sheet zones of the floor of the cut have also been of immediate concern.

Remedial measures recommended are rock bolting of the potential glide blocks; trimming and facing the floor of the cutting to prevent accelerated erosion caused by turbulence; and use of existing rock rubble at the outlet end of the spillway to build gabions to form a training wall on the downhill side.

There is no immediate danger to the main dam structure from defects in the spillway, and an extensive programme of remedial works has included many of the geological recommendations.

INTRODUCTION

Serpentine Dam is a water supply dam on the Serpentine River, 40 miles southeast of Perth.

Construction of a rolled earthfill structure commenced in 1957, and the dam was opened in 1961, but it was not until the winter of 1964 that the reservoir was filled, and water was discharged down the spillway. The weir type spillway with Tainter Gate control is on the right hand bank of the river, the partially lined bywash channel running along the valley slopes before releasing the water freely downhill.

The flood discharges of 1964 caused erosion and damage to parts of the unlined bywash and this report records the result of investigations made at the request of the Metropolitan Water Supply, Drainage and Sewerage Board (M.W.S.). Remedial works were carried out in 1965, and all the major problems appear to have been successfully overcome.

GEOLOGY OF THE SITE

Physiography

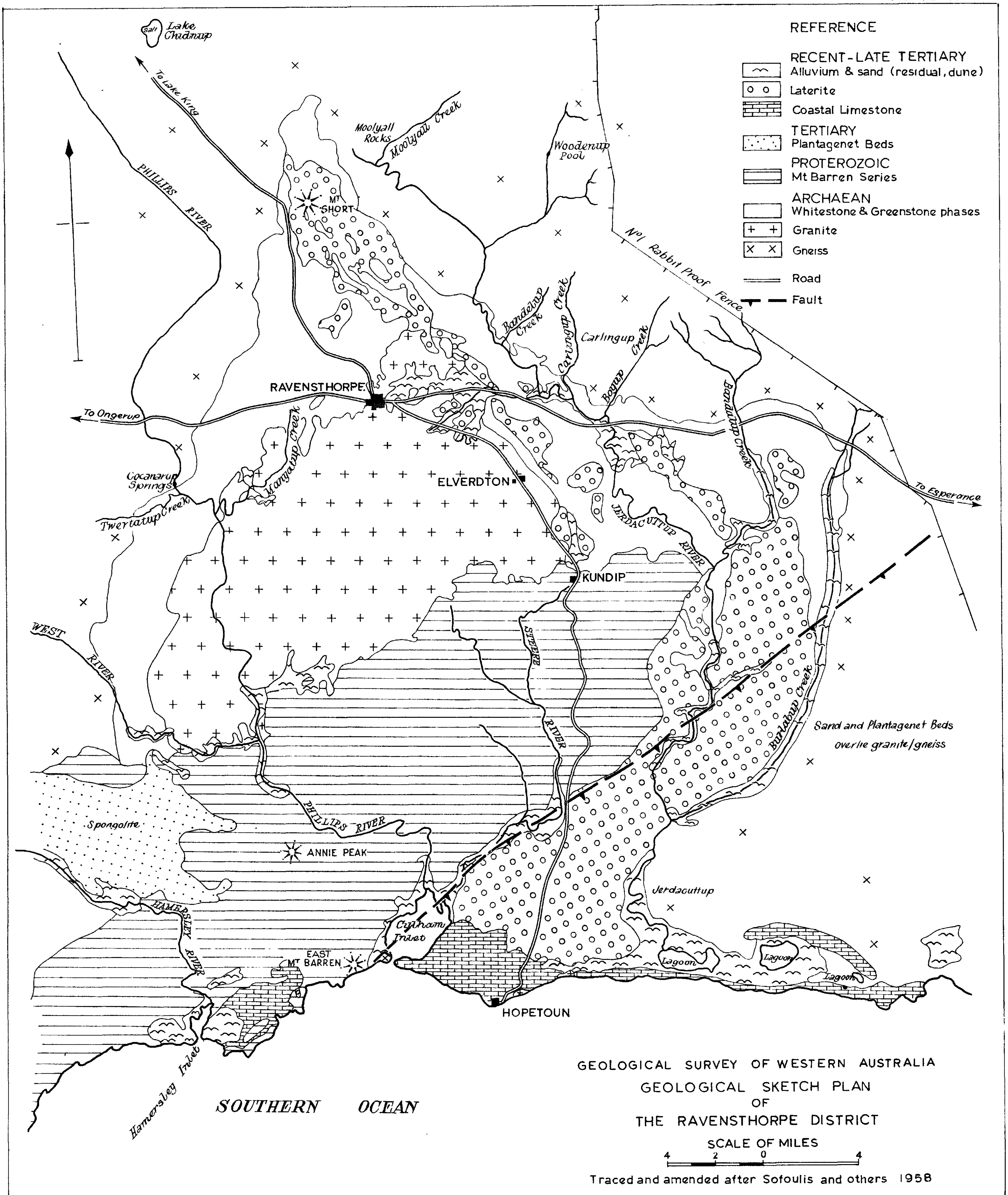
The dam site is high on the Darling Scarp, which forms the western face of the Darling Ranges and separates the ancient peneplain from the Swan Coastal Plain. Granites and granitic gneisses with subordinate minor basic intrusives make up the Precambrian complex of both peneplain and scarp. The Serpentine River has incised a physiographically youthful valley about 300 feet deep into the scarp. At the dam site the valley is asymmetric in section. The northern side, with outcropping tabular masses of gneiss, is much steeper than the southern side, which contains a considerable thickness of completely weathered rock above fresh gneiss. On the northern side of the valley the dominant physical weathering activity is the removal of rock debris from large-scale exfoliation shells or sheet joint surfaces. This is in contrast to the dominant chemical decomposition of the rock on the southern side that has produced a weathered mantle as much as 60 feet thick.

Rock types

Most of the spillway is cut in a medium to coarse-grained porphyritic granite gneiss, white and green-grey in colour. Over short distances there are abrupt changes in the rock type and variants include unfoliated quartzose granite; dark, basic, strongly banded gneiss; acid felsitic and aplitic granites; and weakly foliated gneiss with amphibolite schlieren or segregations. The foliation strikes from 130° to 140° and dips at about 50° to the north; this strike direction is favoured by aplitic and epidotised veins. Veins of pegmatite are rare, but clots of chalcopyrite are found occasionally in the gneiss.

Dolerite dykes, ranging in width from 9 inches to 40 feet, strike across the cut, with a preferred orientation of between 160° and 202°. Some dykes are unsheared at the margins, while others show signs of movement on one or both margins.

Apart from dominant sheet joints the granite gneiss has few strong joint sets, and excavation of the rock has been governed by local rock variations and by excavation methods. In particular, the effect of overloading the bottom of shot holes is plainly seen, with a zone of weakened rock and induced joints extending in a spherical-shaped zone from the bottom of the shot hole. The dolerite dykes are strongly divided by major joint sets, and the effects of overloading are not so marked


REFERENCE
RECENT-LATE TERTIARY
Alluvium & sand (residual, dune)
Laterite
Coastal Limestone
TERTIARY
Plantagenet Beds
PROTEROZOIC
Mt Barren Series
ARCHAEAN
Whitestone & Greenstone phases
Granite
Gneiss
Road
Fault
Lake Chidnup
Salt
To Lake King
PHILLIPS RIVER
Moolyall Rocks
Moolyall Creek
Woodenup Pool
MT SHORT
No 1 Rabbit Proof Fence
Bandalup Creek
Carlingup Creek
Carlingup
Bogup Creek
Bandalup Creek
RAVENSTHORPE
To Ongerup
To Esperance
Manyatup Creek
Cocanarup Springs
Twertatup Creek
ELVERDTON
JERDACUTTUP RIVER
KUNDIP
WEST RIVER
STEERE RIVER
Burlabup Creek
Sand and Plantagenet Beds overlie granite/gneiss
Spongolite
PHILLIPS RIVER
ANNIE PEAK
HAMERSLEY RIVER
Culham Inlet
EAST MT BARREN
Jerdacuttup
Lagoon
Lagoon
Lagoon
HOPETOUN
Hamersley Inlet
SOUTHERN OCEAN
GEOLOGICAL SURVEY OF WESTERN AUSTRALIA
GEOLOGICAL SKETCH PLAN
OF
THE RAVENSTHORPE DISTRICT
SCALE OF MILES
4 2 0 4
Traced and amended after Sofoulis and others 1958

because much of the explosive effort has been absorbed in the existing joints. For this reason the main dolerite dyke stands higher in the floor than the surrounding gneiss. In the smaller dykes the jointing is strong and sufficiently simple to allow them to be eroded quickly by flowing water, and these minor dykes are often considerably over-deepened on the floor of the cutting.

Sheet joints

Sheet structure or large-scale exfoliation is the division of rocks by flat to gently curved fractures, "seams", or partings. Thin lenses and tabular masses ("beds" or sheets) are most conspicuously developed near the surface of the rock where they are generally parallel with the surface. With increasing depth, the sheets tend to become progressively thicker, more nearly horizontal and less irregular.

If traced far enough, most of the intersheet fractures or exfoliation planes can be seen to merge with adjacent fractures, while some gradually decrease in intensity and disappear. Others die out abruptly or terminate against older, more steeply dipping joints, faults or shear zones. There is thus a clear distinction between the sheet joint planes and the joints or faults formed during consolidation of the rock or as a result of tectonic activity. Sheet joints are the result of relaxation of loaded rock masses following erosion. The unloaded rock tends to expand and does so by fracture whenever internal stress exceeds the elastic strength.

Rock weathering

Although physical weathering processes appear to have been dominant on the northern side of the valley, chemical decomposition of rocks has proceeded in topographically sheltered areas and down major openings such as sheet joints, fault zones, sheared dyke margins, and in heavily jointed rocks. The in situ breakdown of rocks has been limited by the dominance of sheet joints, and instead of a gradation from completely weathered rock at the surface to fresh rock at depth, layers of rock of similar degrees of weathering have been produced, and the transitions may be sudden. It is not unusual to have a layer of residual clay (completely weathered gneiss) above a strong sheet joint, and grey gneiss, unweathered except for limonite stained joints, immediately underneath (Plate 13).

Various degrees of granite rock weathering have been defined by Moye (1955), and the applicable local modifications are given in the Table on Plate 12. Slope wash material, soil and the various laterites have been omitted from the sequence.

EROSION AND STABILITY PROBLEMS

All the problems concerning the erosion and stability of the spillway result from the presence of sheet joints, because the completely weathered seam found enclosing the larger joints is readily eroded by water, and where the joints are steeply dipping the excavation of the spillway has made sliding possible.

Scour of discharge area

The geological situation in the area beyond 1,035 feet where the bywash turns downhill to discharge the water freely is shown on Plate 12. Three major sheet layers and two weathered shear zones converge in this area and selective erosion and scouring down these has lead to the undermining and subsequent collapse of large blocks of gneiss. A rock pile about 100 feet high is growing rapidly from the valley floor, and soon will reach to just below the outlet, but this is not necessarily a bad situation, although an unsightly one. Further collapse is inevitable, especially on the western side of the outlet, where there is a vertical face with clay over sheets of granite gneiss, and the interstitial sheet surfaces are deeply undercut. Downcutting at the outlet at one section has resulted in the water flow being concentrated in a narrow channel less than 10 feet across. This has caused accelerated erosion, with a hole about 8 feet deep being cut in one of the weathered shear zones. Below this channel there is a vertical drop of about 12 feet, and the water falls on to a sheet surface dipping at about 35 degrees downhill. There are no defects in this block as it has been below the depth of weathering, and development of this surface promises to give ultimate stability to the whole area.

If the water was discharged downhill before the affected area is reached, the same wholesale undermining of gneiss sheets, and the subsequent collapse, would undoubtedly commence. While further major falls may be expected in the present discharge area, they are not likely to have any effects on the main dam structure.

Erosion of the spillway wall

From 740 feet to 850 feet (centre line) a major exfoliation joint zone forms the toe of the downhill batter of the cutting. There has been considerable erosion of the clay filled zone which is between 2 and 3 feet wide, and overhangs up to 10 feet deep have formed. This selective erosion has been encouraged by the shape of the bywash floor as the uphill side is in places considerably higher than the downhill side, and in addition, a major dolerite dyke has been left high across the cut floor immediately upstream of the eroded area, causing both increased velocity of flow, and concentration of flow on the downhill wall. From 730 feet to 770 feet the downhill wall is about 18 feet high and is formed of weathered granite gneiss in the form of yellow and white clay. The cut floor is formed of moderately weathered gneiss, and between the two is the sheet joint zone, about 2 feet 6 inches wide, consisting of completely weathered gneiss which has been eroded to leave overhangs of as much as 4 feet. Between 770 feet and 800 feet the condition of the rocks improve and the wall is of moderately weathered rock, the sheet zone is completely weathered and the floor is of slightly weathered gneiss. The exfoliation zone dips at about 15 degrees southwest, i.e., downhill. From 800 feet to 860 feet, slightly weathered gneiss or fresh gneiss with limonite stained joints is found on either side of the 2-feet-wide zone of completely weathered rock, but in the batter, highly weathered gneiss occurs a few feet above the sheet zone. An overhang of about 10 feet has developed in this area, and the dip of the zone is as high as 35 degrees to the southwest. From 850 feet to 900 feet the sheet zone is above the floor and is thus protected to a certain extent. The weathered zone east of this area decreases in size to two seams about 6 inches thick and a few inches apart.

The erosion of the sheet zone in this area must be considered as a major problem, as failure of the spillway wall could lead to damage to the toe of the dam and also to the outlet structure.

Scour in the spillway floor

There are two deep holes on the floor of the spillway. These have formed along the strike of exfoliation joints in areas where dolerite dykes crossing the floor have allowed lateral extension of erosion. In particular, a 9-inch-wide dolerite dyke striking at 030 degrees across the centre line at 935 feet shows simple cooling joints and slightly sheared margins, and blocks have been removed to about 6 feet in depth. The gneiss on the hanging wall side is now about 3 feet lower than the rock at floor level on the footwall side.

The two depressions are not of any great significance. Continued erosion will be largely in a vertical direction because the sheet joints are steepening rapidly in dip. The holes should be repaired in order to prevent turbulence.

Clay and debris slides on exfoliation surfaces

The sidehill cutting of the bywash channel has intersected sheets of rock of varying mechanical condition lying in the dip downhill. In some areas the upper rock layers have been completely weathered into a clay, and many of these sections are unstable because the batter face is over-steep and the underlying exfoliation surface is steeper than the critical angle and is occasionally lubricated.

Some large slides have already occurred, and signs of incipient fall are not rare. The most serious result of a big fall would be to divert the water flow against an easily eroded part of the downhill wall.

From 700 feet to 770 feet, centre line dolerite, completely weathered to a clay, stands at a slope of about 75 degrees in the uphill wall. The clay, 10 to 15 feet thick, is lying on an exfoliation surface that dips into the cut at about 15 degrees, and fresh dolerite with limonite-stained joints forms the lower part of the wall about 15 feet high. Tension cracks are visible in the clay, and there is a sharp separation from the adjacent weathered gneiss, suggesting that there has already been minor movement. In the uphill wall between 920 feet and 980 feet centre line, the major exfoliation surface is about 15 feet above the floor and dips into the cutting at about 30 degrees. The sheet joint is a plane separating complete weathering products in the form of clay from fresh gneiss with limonite-stained joints below. Some large masses of clay have already slid out on the joint surface, and others will doubtless follow.

Block glide and rockfall on exfoliation surfaces

Between 980 feet and 1,040 feet centre line, the uphill wall is about 30 feet high and has a slope of 70 degrees. About 15 feet above the floor a major exfoliation zone about 2 feet wide dips at 33 degrees into the cutting. Of the four joints in the zone, the topmost parting of about 3 inches is of clay minerals. Above this main joint-zone, the rock mass is divided by two other sheet joints, but these do not contain clay or show signs of the water seepage that is clearly visible in the major zone. At 980 feet centre line there is an abrupt discontinuity where a 9-inch-wide dolerite dyke strikes behind the face, and the dolerite dyke and the adjacent gneiss to the east are completely weathered down to the main exfoliation layer. At 1,040 feet the sheet joints dome up and there is minor vertical jointing at right angles to the face. All the conditions necessary for block gliding are present on the uphill wall. This area should be stabilized because blocking of the spillway in this area would cause severe scouring of the hillslope. It would also cause complications round the outlet control structure and may even effect the parking area on the south bank of the river.

From 1,040 feet to 1,080 feet the major exfoliation joint dips into the cut at 35 degrees, but the surface, which is 15 feet above the floor at 1,040, bends round to meet the floor at 1,080. The clay parting does not appear to be present, and other planes of possible separation are not apparent, consequently the risk of block gliding is not considered high. However, some strengthening procedure may be a worthwhile form of long-term insurance.

CONCLUSIONS

1. The bywash channel has been cut in a sidehill location on a slope where sheet jointing accentuated by weathering has caused strong divisions and contrasts in the condition of the granite gneiss and dolerite rocks.

Scouring and accelerated downcutting have been caused by the passage of water during the first year of overflow.

2. The stability of sections of the uphill wall is in doubt, where steeply dipping sheet joint surfaces are favourably disposed for debris slides or block gliding of rock masses. Rock bolting is considered sufficient to stabilize the potential block glide, and trimming back of steep clay faces is recommended.

3. A highly weathered sheet zone at the toe of the batter of the downhill wall has been deeply scoured, and water flow has been concentrated on this area because of irregularities in the rock floor. Remedial works should include trimming of the floor, filling the cavities and facing with a dry stone wall, followed by pinned mesh and a gunite coating.

4. Eroded holes in the floor of the spillway and near the outlet should be filled in to prevent accelerated erosion and to minimize turbulence. Prepacked concrete is suggested as an economical and effective measure.

5. The rock rubble forming the side of the bywash near the outlet would be more effective if used to fill gabions to form a wall.

6. Further downcutting and erosion below the spillway outlet must be expected. Ultimately a stable configuration may be achieved on a strong sheet of gneiss now showing at the foot of the waterfall. Prepacking of eroded holes is recommended.

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GEOLOGICAL INVESTIGATION OF THE GOGO DIVERSION DAM SITE

by E. E. Swarbrick

SUMMARY

The proposed dam is located in the valley of the Fitzroy River between two outcrops of the Permian Grant Formation. The valley is partly filled with Recent alluvial sediments which overlie the Grant Formation. At various times the two lowest units of the Grant Formation, a brown platy mudstone overlying a white siltstone, have been involved jointly in slumping, and this is likely to occur again.

Overlying the mudstone is a series of alternating sandstones and mudstones up to 140 feet thick which form the major part of the outcrop on the abutments.

The Recent alluvial sediments are at least 100 feet thick over a large part of the foundation area. In the thickest section (Plate 14) there is a known maximum of 70 feet of very coarse sand and gravel which is well sorted, permeable and believed to extend for at least a mile upstream. Elsewhere the oldest alluvium ranges from silt to medium sand. The youngest alluvium is silt which covers most of the area, and is 10 to 30 feet thick. The upper 6 to 10 feet of this sequence is invariably a grey-brown silty soil. In the channels of the major watercourses i.e. Fitzroy River and Sandy Creek, are medium to coarse sand and gravel. The vertical extent of these sediments has not been tested by drilling, but if the channels have retained the same general position for any period of time these sediments could be quite thick.

The older rocks of the area are folded into a gentle syncline with a northwesterly trending axis, lying about 200 feet to the south of the pegged centre line. Joints are well developed on the left abutment but not on the right. Where they occur some leakage is to be expected, but this is not thought to constitute a major problem.

Both abutments are considered to be reasonably sound but the nature of the foundation rocks in the valley bottom will create problems. The thick, permeable, coarse sands and gravels, covering the valley floor and in the channels of Fitzroy River and Sandy Creek, must be sealed if the structure is to achieve its intended purpose.

Further problems could be caused by the proximity of Mellonhole Creek to the upstream toe of the dam. In the early and later stages of any major rainfall period this creek will flow strongly and scour. It will need to be diverted and relocated.

Two spillway sites are available, both sited on outcrop. One occurs between 9,000 and 10,000 feet on the pegged centre line (Plate 14) and the other may be placed on the outcrop west of the Fitzroy River wherever the elevation is suitable.

The problems concerned with the proposed construction of this dam are such that it is strongly recommended that no further commitment for field investigation be made until all reports have been considered in detail.

WEATHERING IN GRANITE ROCKS

Symbol	Description
CW	Completely Weathered, in places to a sandy clay.
HW	Highly Weathered, rock fabric, recognisable, can be broken by hand
MW	Moderately Weathered. Considerably weathered but NX core pieces resist breaking in the hands.
SW	Slightly Weathered, limonite stained Feldspars dull, strength high
LSJ	Limonite stained joints, rock fresh
R	Fresh rock

LEGEND

- Strike and dip of joint
- Vertical joint
- Strike and dip of foliation
- Exfoliation joints, enclosing zone of weathering, showing dip
- Fault, shear plane showing dip
- Deeply scoured areas

ROCK TYPES

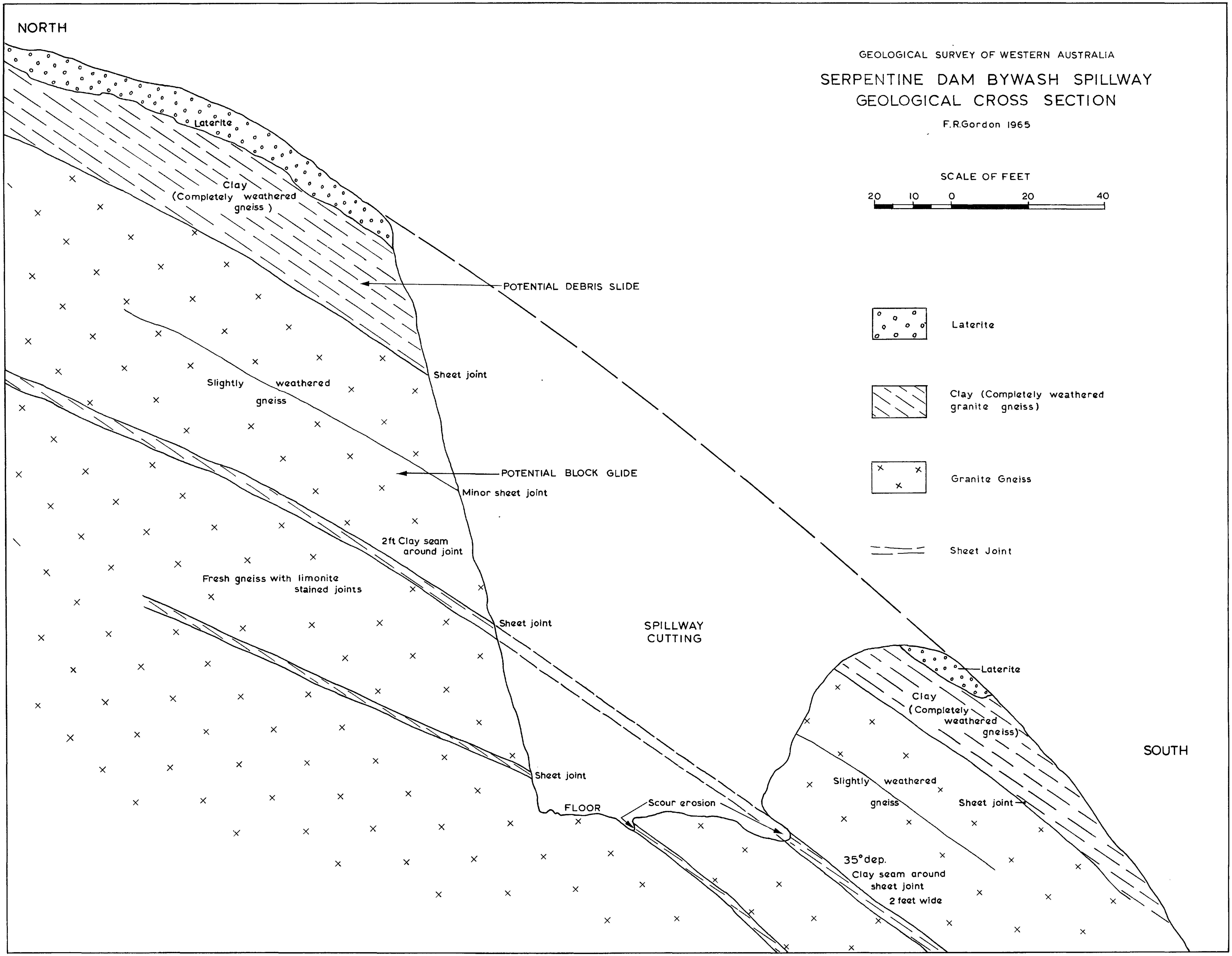
- Granite gneiss
- Dolerite dykes

GEOLOGICAL SURVEY OF WESTERN AUSTRALIA

SERPENTINE DAM BYWASH SPILLWAY
Unlined Section
GEOLOGICAL PLAN

Date 1965 — F R Gordon

8555


GEOLOGICAL SURVEY OF WESTERN AUSTRALIA
SERPENTINE DAM BYWASH SPILLWAY
GEOLOGICAL CROSS SECTION
F.R.Gordon 1965
SCALE OF FEET
20 10 0 20 40
Laterite
Clay (Completely weathered granite gneiss)
Granite Gneiss
Sheet Joint
NORTH
SOUTH
Laterite
Clay (Completely weathered gneiss)
POTENTIAL DEBRIS SLIDE
Sheet joint
Slightly weathered gneiss
POTENTIAL BLOCK GLIDE
Minor sheet joint
2ft Clay seam around joint
Fresh gneiss with limonite stained joints
Sheet joint
SPILLWAY CUTTING
Sheet joint
FLOOR
Scour erosion
Laterite
Clay (Completely weathered gneiss)
Slightly weathered gneiss
Sheet joint
35° dep.
Clay seam around sheet joint 2 feet wide

INTRODUCTION

The dam site is located on the Fitzroy River approximately 7 miles southwest of the small town of Fitzroy Crossing.

The dam will divert into irrigation channels, the water being released from storage dams to be built upstream. The diversion dam will be approximately 19,000 feet long, 100 feet wide at the base, 20 feet wide at the top and will have a maximum height of approximately 60 feet. Top storage level will be R.L. 360 feet.

The surrounding country consists mainly of flat plains of alluvium and red soil, occasional relief being afforded by low remnant hills, usually rising less than 200 feet above the level of the surrounding plains. Two such hills form the abutments of the proposed dam.

At the request of P.W.D. Planning, Design, and Investigation Branch, two main investigations were made and this report covers the geological field mapping augmented by Gemcodril auger boring. An investigation by seismic refraction methods was made by D. L. Rowston of the Geological Survey (1965) assisted by E. Gumela of the Snowy Mountains Hydro Electric Authority.

The centre line chosen by the Geological Survey was surveyed and pegged by P.W.D. Surveyor D. M. Attrill, and reference to this survey will be of the form ". . survey control peg No. A6 . ." etc. (Plate 14).

GEOLOGY

STRATIGRAPHY

A generalised stratigraphic column through the dam site is given below:

Alluvial sediments— *Recent*	grey-brown silty soil 6 to 10 feet brown silt 20 to 25 feet very coarse sand and gravel 70 ± feet
	Unconformity
Grant Formation— *? Permian*	alternating sandstone and mudstone 90 to 140 feet brown porcelanous mudstone 7 in. to 5 feet white siltstone 4 to 5 feet

Grant Formation

The *white silstone,* lowest unit of the Grant Formation, outcrops on the western edge of Alligator Hill on the northwestern abutment (Plate 14), and at the base of low breakaway cliffs southwest of Alligator Hill. In outcrop the rock varies from a hard, white, quartzose siltstone, to a soft white to grey, clayey silt, very similar to the weathering product of granitic rocks. Where the rock is soft (deeply weathered) there is evidence of recent slumping. It is believed that a Gemcodril auger sample of this rock would be virtually indistinguishable from alluvial silt. Where the rock is cemented, it is sufficiently strong to resist moderate river scouring, but could be readily drilled by a Gemcodril auger. Such a characteristic is important in the interpretation of Gemcodril auger samples and previous results are open to some doubt on this score. Thus the soft white siltstone encountered at depths of 30 to 40 feet in Gemcodril Holes Nos. 5 and 6 may be Grant Formation.

The most westerly and southwesterly outcrops show evidence of movement shortly after deposition, and consequent disruption and slumping of the overlying strata.

Brown porcelanous mudstone with very distinctive deep-brown outcrops, is exposed in all parts of the dam site and has been employed as an index horizon. The rock is a hard, compact, laminated and well bedded mudstone and is invariably deeply ferruginised. The mudstone is brittle and weathers into flat, flag-like slabs up to 1 inch thick, forming extensive areas of talus.

The base of the unit is frequently characterised by rounded mudstone balls with a high iron oxide (? limonite) content and botryoidal structure that protrudes down into the underlying siltstone. They are at present concretionary but may have developed from primary sedimentary structures such as load casts. The suggestion of original differential loading and movement is strengthened by clear evidence of local intraformational movement between the mudstone and the underlying siltstone. Thus the mudstone west and southwest of Alligator Hill appears to have been disturbed very soon after consolidation, leading to slump structures and box structures. The latter are formed by slabs of mudstone standing on edge, and arranged in a rough square or circle by the slabs dipping inwards or outwards or standing vertically. In outcrop the mudstone is clearly seen to occur as slumped masses.

It is believed that these structures result from a rapid consolidation and hardening of the mudstone (possibly due to the setting of some incorporated gel material) while the underlying silt unit was still potentially highly mobile. Under the influence of some motive force such as differential loading or gravity-induced movement down a submarine slope, lateral flow occurred in the mobile silt. This led to disruption of the overlying mudstone and local slumping of that layer. It also led to differential hydrostatic pressures within the fluid silt. Thus in some places the silt was forced up through the mudstone in diapiric fashion leading to the formation of box structures with outward dipping or vertical slabs; in other places the mudstone collapsed down into the siltstone causing the box structures with inwards dipping slabs.

Mount Campbell and Alligator Hill are formed from a sequence of *quartzose sandstones, mudstones, and siltstones,* which are the youngest members of the Grant Formation exposed in the area.

The sandstones are red-brown to grey and white, medium-grained, well rounded, moderately to well sorted, and usually have a high coefficient of sphericity. The mudstones are white to pale grey, with occasional purple bands, and are hard, compact and semi-porcelanous.

At two distinct horizons, on both Mount Campbell and Alligator Hill, are layers with worm tubes (serpulites) which are tentatively used as index horizons.

At Mount Campbell and Gogo Hill the unit is 140 feet thick, and 90 per cent of the rock is sandstone. To the northwest, a major facies change is evident, with the sandstone being replaced by mudstone and siltstone. The succession at Alligator Hill, although only 90 feet thick, can be closely correlated with the succession at Mount Campbell. Both have the brown platy mudstone unit at the base, the two serpulite bands, and evidence of intraformational erosion near the top.

McWhae and others (1958) state that the Grant Formation includes glacial sediments, but these are not evident in the area of the dam site. Sedimentary structures are fairly common and include intraformational erosion structures, rapid facies changes i.e. from sandstone to mudstone in a matter of a few feet, and ?dessication breccias and sun cracks. These structures suggest shallow water deposition in an area of minor but constant movement. The dessication breccias and sun cracks may also suggest a warm climate.

Recent alluvial sediments

During the 1965 investigation, twenty Gemcodril holes were put down on or close to the pegged centre line. Logs of samples from these holes are available for inspection at the Geological Survey office.

In holes 1, 2, 3, 4, 10, 15, 16, 17 and 18, *coarse to very coarse sands and gravels* were encountered between the depths of 30 and 100 feet. In the majority of cases these sediments occupy the whole or a substantial part of this interval. Contaminating the coarse sediments in these samples are brown silts and clays in sufficient quantity to render the whole reasonably impermeable. These silts are indistinguishable from a silt sequence which lies above the coarse sediments in each case, and it was considered that major contamination of the coarse sediments may have taken place during drilling. It was therefore decided to core the coarse sediments and a core hole was sunk with a 5-inch auger close to Gemcodril hole No. 15. Great difficulty was experienced in achieving penetration with the coring tool, and upon recovery the tool was found to be damaged. A good sample was obtained between the depths of 32′6″ and 33′9″ and is logged as:

Sand, quartz, and quartzite fragments, coarse to very coarse-grained with a large gravel content, fairly well sorted, grains are subangular. A small silt component (less than 5%) is present. This sediment is obviously highly permeable and is water saturated.

Further coring was attempted with a new coring tool close to Gemcodril hole No. 17. During the operation, the coring tool was sheared off from the core barrel and no sample was recovered.

Although only one core sample has been recovered, the consistent nature of the auger samples of the coarse sediments (including those from Gemcodril Hole No. 15) indicates that these sediments will be found in all cases to be identical with the core sample. From Plate 14 it will be seen that the gravel occupies a wide depression in the rock surface. There is a depression of similar extent and shape one mile to the north and the coarse sediments probably occupy an ancient river channel of the Fitzroy River.

A unit of *brown silt* with a minor clay admixture, 20 to 25 feet thick occurs above the coarse sand and gravel horizon in each hole.

The youngest alluvial unit in the area of the dam site is a *grey-brown silty soil* which ranges from 6 to 10 feet in thickness. It is a typical flood plain deposit which covers all outcrops of other rock units, but which is locally absent along the channels of watercourses such as the Fitzroy River and its major tributary, Sandy Creek. These channels are filled with medium to very coarse sands, gravels and cobbles (river shingle).

Although coarse sand and gravel were encountered in most of the holes put down, other holes penetrated somewhat different alluvial profiles. For example, below the normal grey-brown, silty soil—brown silt sequence in Holes 5 and 6, there is a series of grey, pink, white, and mauve siltstones. These siltstones have the appearance of solid rock and are very similar to the mudstones of the Grant Formation on Mount Campbell. They are soft enough to drill with a 2-inch auger bit. It is possible that the rock is a reconstituted weathering product derived from Mount Campbell, or that the holes penetrated the lowest known horizon of the Grant Formation occurring in the area, i.e. the white siltstone unit (as noted before, this rock in outcrop is frequently soft enough to be auger drilled). The colour of the samples, however, is atypical of this unit and it seems likely that the rock encountered is a siltstone equivalent of one of the younger mudstone horizons. This is supported by evidence from seismic velocities, although evidence from Holes 7 and 7A, located approximately 10 chains north of Hole 6, casts some doubt on this conclusion. Hole 7 penetrated white siltstone fragments between hole depths 29 and 36 feet and white and brown siltstone from 36 to 38 feet, at which depth no further progress could be made. Hole 7A which was drilled 10 feet from Hole 7, showed no siltstone, and from 36 to 105 feet penetrated only brown, silty and sandy clay. Thus, whereas the results from Hole 7A apparently agree with those from Holes 5 and 6 in suggesting Grant Formation occurring at about 40 feet depth, Hole 7A continued 60 feet below this horizon in true alluvial sediments. While it seems possible therefore that Grant Formation was intersected at about 40 feet depth, the evidence from Hole 7 and 7A suggests that such a conclusion be approached cautiously.

West of the area of gravel occurrence, Holes 19 and 20 penetrated a sequence different from both those described above. Below the semi-soil profile both holes penetrated the usual brown silt sequence which in Hole 20 is thinner than is usual, i.e. only 12 feet thick. It may be significant that due to a low ground elevation in this area, the base of this unit is at approximately the same R.L. as in other areas. Below this brown silt unit, Holes 19 and 20 penetrated medium to fine sandstone, well washed and free. Both these holes were drilled immediately adjacent to Mellonhole Creek and *may* represent a continuous section of channel deposits. It seems more likely that this sand is a fine-grained facies of the large gravel unit lying to the east.

Holes 8 to 14 inclusive which were drilled around the proposed spillway site encountered only white siltstone (thought to be reconstituted weathering products) and alluvial silt ranging from 6 to 100 + feet thick and presumably overlying the Grant Formation which crops out close by.

The base of the silt, which lies between the soil profile and the coarse sediments, etc., is found in the drill holes from seismic evidence (Rowston, 1965) to be remarkably level at about R.L. 300 feet. This suggests that the silt may represent an ancient soil profile, a thesis which is supported by observations of a second soil profile at depths of 30 to 40 feet in Holes 2 and 6. The "siltstone" penetrated in Holes 5, 6 and 7 in these holes lies immediately below the silt in question, and may therefore represent the remains of an ancient calcrete deposit.

Also from seismic evidence (Rowston, 1965), it is likely that this "ancient soil profile" silt is absent below the present bed of the Fitzroy River. Seismic velocities in this zone are lower than is normal for this silt horizon (5,000 feet/sec compared with 5,500 feet/sec), which suggests that below the river bed the silt has been replaced by sand, so that the coarse sand and gravel filling the present river channel possibly continue to the subcrop of the Grant Formation at depth 120± feet.

STRUCTURE

Folding

The rocks of the Grant Formation are folded into a gentle syncline with the axis trending approximately northwestwards and lying about 2,000 feet to the south of the pegged centre line.

Jointing

Besides the usual structural control of joints in the area of the dam site there is also a lithological control. The predominantly sandy rocks of Mount Campbell have well developed joint sets in both sandstone and mudstone beds. However, the predominantly muddy rocks of Alligator Hill have only occasional and usually solitary joints confined to the rare sandstone beds. Furthermore, a comparison of joint rosettes, taken on sandstone beds and mudstone beds on Mount Campbell, shows a difference of trend of major joint sets (Fig. 8). The most persistent joint set in the area is vertical to steeply dipping with a trend to approximately 320 degrees magnetic (Set 1). This set is approximately parallel to the axial plane trend of the shallow syncline in which the outcrops lie, and has almost certainly resulted from the folding movement.

Within sandstone beds on Mount Campbell, and on other sandstone outcrops, a second important joint set trends to 080° magnetic (Set II) and dips both to north and south at 65° to 90°. On mudstone beds this set II is poorly developed, and set III is the second most important, being vertical and trending between 010° and 050° magnetic.

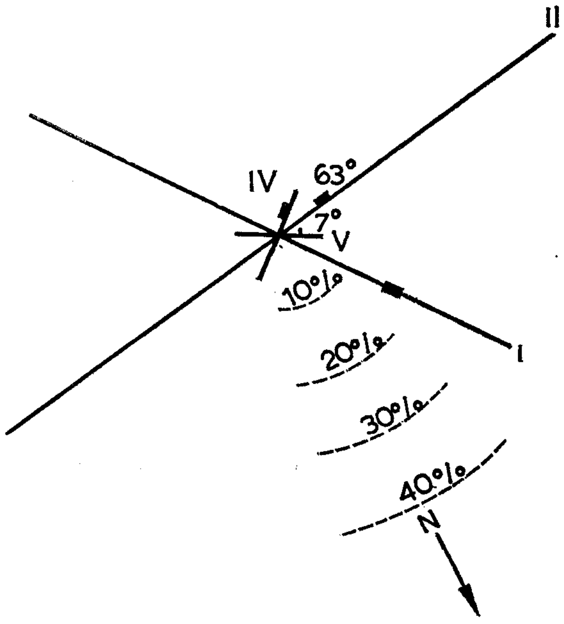
Joints are generally fairly tight, the maximum degree of opening being from ⅛ to ½ inch. Occasional evidence of minor movement can be seen. The difference between important joint trends in sandstone beds and mudstone beds results in a general lack of vertical continuity from bed to bed.

The discontinuous outcrop precludes any detailed study of relationships between dominant joint sets and observed trends of natural features. However, the course of the Fitzroy River north of the centre line suggests a possible influence by joint set III, i.e., the major mudstone joint direction. The greater hardness of the mudstone would tend to exert more control than the sandstone.

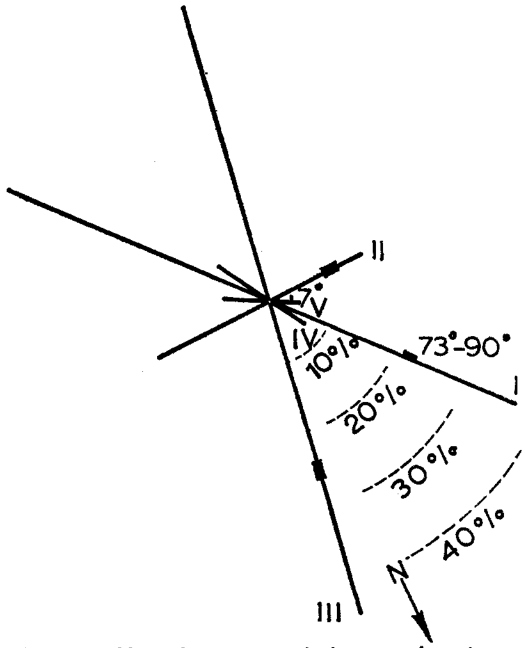
SITE APPRECIATION

FOUNDATION ON THE VALLEY SIDES

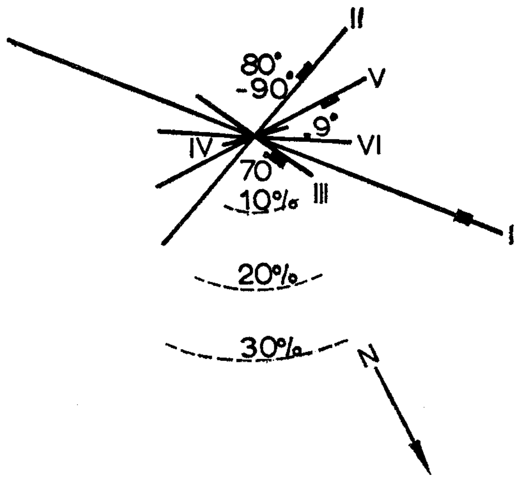
Both abutments are reasonably sound, Alligator Hill being the better of the two because of the predominance there of impermeable mudstone and the general lack of joints. At Mount Campbell leakage is likely through sandstone and well developed, numerous joints. With top storage level at R.L. 360 feet however, only the lowest levels of this abutment will be flooded.



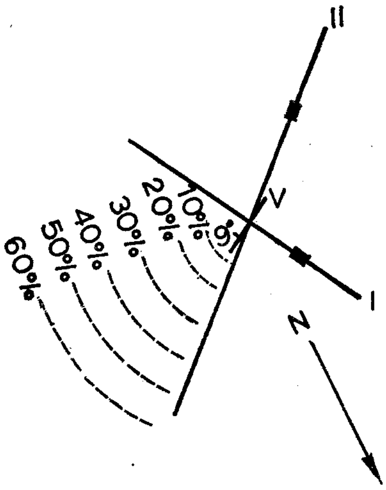
Joint rosette for sandstone beds on Mount Campbell



Joint rosette for mudstone beds on Mount Campbell



Joint rosette for outcrop at survey control peg A6



Joint rosette for outcrop on south western bank of the Fitzroy River

FIGURE 8: GOGO DIVERSION DAM SITE, ROCK JOINT PATTERNS

FOUNDATION IN THE VALLEY BOTTOM

Immediately to the northwest of Mount Campbell, rock is at a shallow depth, and is also likely to leak, although this will not constitute a major problem.

From Survey Control peg No. A6 (Plate 14) northwestwards to beyond the northwestern bank of the Fitzroy River, foundation conditions are unsatisfactory. The very permeable coarse sands and gravels below the foundation will allow considerable water movement below the dam. Similarly the permeable sediments occupying the bed of the Fitzroy River could extend to a considerable depth.

Unless these two highly permeable bodies of sediment are effectively sealed, it is unlikely that the structure will hold a satisfactory amount of water.

Spillway sites

Two spillway sites have been considered. Site 1 is located on the outcrops lying on the immediate southeast bank of the Fitzroy River between 9,000 and 10,000 feet (Plate 14). The pegged centre line has been located on the more northerly of the two outcrops, to allow the maximum length of outcrop downstream of the spillway. Gemcodril auger boring around the two outcrops has established the presence of a deep channel on their northwestern side, which may be part of the present river channel system. Downstream of the spillway site however, rock occurs at shallow depths.

Site 2 could be located anywhere on the outcrop west of the Fitzroy River, dependent on elevation. Outcrop is continuous, and construction of a concrete spillway would be a simple matter.

Influence of watercourses

At a certain stage of the wet season, many of the watercourses upstream from the dam site would flow for considerable periods of time before the proposed storage lake was filled. Erosion by these courses along the foot of the dam could have a serious effect on an earth structure.

In this respect Mellonhole Creek could not be more disadvantageously situated. In order to utilise existing outcrop to the utmost, the centre line must run for a considerable distance on or close to the northern bank of this creek. Two solutions are available: (a) move the centre line; to do this would mean either foregoing the assistance of existing outcrops or having several bends in the centre line or (b) attempt to minimise or prevent erosion by diverting the creek and filling the present bed with heavy ballast. The latter would seem the more realistic approach.

CONCLUSIONS

The valley of the Fitzroy River at the Gogo Diversion Dam Site is partly infilled with at least 100 feet of alluvial sediments, a large proportion of which are highly permeable sands and gravels. The foundation of the proposed dam therefore has an extremely high leakage potential, and the area may be economically unsuitable for the construction of a dam. There is no reason to believe that alternative sites within reasonable distance of Mount Campbell and Alligator Hill (which are the only possible abutments in the area) would furnish a more suitable foundation. It is strongly recommended therefore, that no further field investigation work be carried out until all investigation reports have been considered in detail.

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AN APPRAISAL OF NO. 2 ROCK CUT, STANDARD GAUGE RAILWAY, AVON VALLEY DEVIATION

by F. R. Gordon

ABSTRACT

The banded gneiss and amphibolite rocks at Rock Cut No. 2 of the Avon Valley Deviation of the Standard Gauge Railway have been extensively modified by chemical weathering and mechanical breakage accompanying faulting and folding. Steeply dipping foliation joints striking across the cut and sub-horizontal sheet joints are the dominant structures. The final shape and stability of the walls of the cutting were determined by the influence these geological factors had on the design shape. Further the variations in the rock type and condition were not recognized in the excavation methods employed, and this further modified the shape by areas of overbreak, especially at the toe of the batters.

Examination of the cutting since completion has shown areas where fractures have been formed or accentuated by a form of stress relaxation. These and other areas of instability have been assessed in terms of their origin, and remedial measures for each have been suggested.

INTRODUCTION

Following a request from the engineering consultants (G. Maunsell and Partners), an examination of the No. 2 Rock Cut of the Avon Valley Deviation (Standard Gauge Railway) was made in February, 1964. Problems of rock stability were discussed with the consultants, and geological examinations were made in an attempt to elucidate them. Since then the rock excavation has been completed and the walls barred down, and the heavy rainfalls of winter 1964, have further modified and clarified the situation. This report is a geological appraisal of the state of the cutting at 15th of April, 1965.

The cut is located at military grid reference 406069 and extends from 21 miles 75 chains to 22 miles 14 chains with a maximum cut of 85 feet on the centre line at 22 miles 07 chains. There are two rock batter slopes 40 feet high on the downhill or northern side of the cutting, and three rock batters on the uphill or southern side. The top face on either side is at a slope angle of 45°, with the remaining batters at 60°. Each 40-foot face is separated by a nominal 10-foot wide horizontal bench.

The cutting was previously examined in 1963, when the difficulties which the local geology and the current blasting techniques imposed on stable excavation, were recorded (Gordon, 1963a). It was expected that the mechanical condition of the rocks would improve towards the core of the hill, especially in the granite gneiss at the Northam end, but this improvement did not occur until the bottom 40 feet of the cutting was reached, and then only in the central core of the cutting.

GEOLOGICAL SETTING

Now that the excavation is completed, trimmed down by hand, and exposed to winter rain wash, the cut walls reveal lithology and structure that was not apparent in the weathered mantle at higher levels. While it was known that tension forces producing strong jointing had been dominant in the area, it was found that at depth, folding had caused considerable modification to the structure and the mechanical condition of the rock. Two distinct suites of rock are found in the cutting as follows:

1. For 10 chains at Midland Junction end, the rocks are folded amphibolite with rafts of granite gneiss. The rocks are faulted and folded, and are deeply weathered.

2. The remaining 9 chains to the end of the cutting shows a coarse-grained, foliated granite gneiss, invaded by "dykes" of amphibolite which in places show strong dragfolding.

EXCAVATION METHODS AND GEOLOGY

Control of working

There is a considerable difference between a railway cutting, which ideally should have smooth slopes and precisely defined boundaries, and an open cut quarry site, where the concern has been to remove rock, not to shape walls. This is, in effect, the fundamental difference in approach between principals and designers on the one hand, and the contractors on the other, and unless the system of payment offers incentives for the production of closely defined shapes, then the finished product will be a compromise between bulk excavation methods and the ideal of design. Unfortunately the recent development of perimeter blasting has come too late to be used in the Avon Valley cuttings. On a lower technical level, the skill and experience of the contractors' engineers, foremen and shot firers, and the experience and persistence of the consultants' representative will all be factors influencing the final shape.

Superimposed on these conflicting interests is the manner in which the geology of the site influences the excavation of the cutting. The most important geological factors are (1) the mechanical condition of the rocks as modified by chemical weathering or physical breakage and (2) the orientation of the dominant structural features with regard to the direction of the excavation.

Variations of rock type

The banded gneiss and amphibolite complex in which No. 2 Rock Cut is situated shows a variety of rock types with granite gneiss, quartz veins, basic schist, and amphibolite containing granite rafts; and extensive faulting and folding of all rocks has accentuated the differences between their mechanical properties. During the early stages of excavation it was not possible to predict with certainty the condition of the next slice to be excavated, and uniform loading of all explosive shot holes meant that the softer and more broken areas were considerably overloaded with explosives, leading to damage to the batters. At depth the nature of the rock to be excavated could be predicted with some accuracy by observations of the cutting walls, and the overshooting of certain areas could easily have been prevented by lighter loading and variations of the hole pattern.

Major joints

It was generally assumed (by the writer no less than others) that major joints, striking across an excavation at right angles to its length, were favourably deposed for securing slope stability. In the event, control of the batters of No. 2 Cut proved most difficult, especially in the harder, fresher gneiss encountered at the Northam end of the cutting. The dominant joint planes following the foliation were open as much as 1 to 2 inches at formation level, and with a joint incidence of 1 every 1½ feet, (Plate 15A) the joints tended to channel the effect of the explosive. Much of the force of the explosion was used not in breaking rock but in accentuating the joint openings, causing overbreak and damage to the walls of the excavation.

The other major joint set was provided by sheet joints, but in this cutting they did not exercise as much influence as in No. 1 Cut, because of the strength of the foliation joints and the variations of rock type. In certain areas the sheet joints were well defined, and, as they were mostly parallel to the ground surface, gave rise to joints dipping at high angles towards the cut on the uphill batter. Joint planes containing a clay parting may be considered as potential sliding surfaces at angles steeper than 15 degrees; while if there is no clay filling, the frictional angle may be as high as 25 degrees (Terzaghi, 1962). Of course in order for block gliding to take place, three other planes of detachment must be available, but with foliation joints striking across the cut, two of these are generally present. For long term stability, it is considered advisable to pin the blocks lying on exfoliation planes steeper than 30 degrees, by means of rock bolts, as excavation would lead to loss of benches.

In this cutting it was not possible from surface observation to predict the direction and dip of the minor structural elements, because of folding movements and large-scale alterations of the rock type.

Overshooting the toe of the batter

The area at the toe of a slope or bench is more highly stressed than other contiguous parts of the slope, and this is the area where failure of a slope is likely to start. The shattering of the rock in the toe of the slope by overbreaking as shown in Fig. 11(B), unnecessarily weakens the slope at a point where a concentration of stress has already reached a high level. Overshooting has been achieved on both sides of the cutting, but in particular the area at the Midland end of the uphill batter (Plate 15(B) has been disturbed in this fashion.

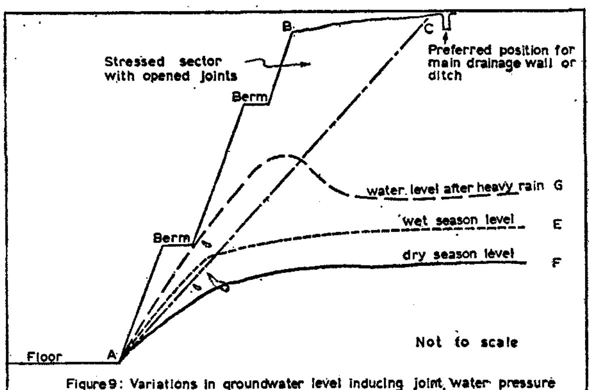

Figure 9: Variations in groundwater level inducing joint water pressure in rock cuttings (after Long, 1964)

Excavation of berms

The difficulties inherent in constructing rock berms as they are designed on paper have already been commented on (Gordon, 1963b). This problem stems from the fact that the bench surface formed part of the floor of a previous lift and has already been damaged by blasting. The excavation of a lower lift has meant further stressing, and if final shaping has to be achieved by trimming shots, the angle formed by the bench and the batter will have been attacked three times, (Fig. 10). As the sheet joints are not dominant in No. 2 Cut the production of a satisfactory bench is not as difficult as in No. 1 Cut. However, oversteepening of the cut walls in the lower portion of the bottom batter by over-shooting the toe, means that the 40-foot bench would have to be eliminated, if design stability were to be regained.

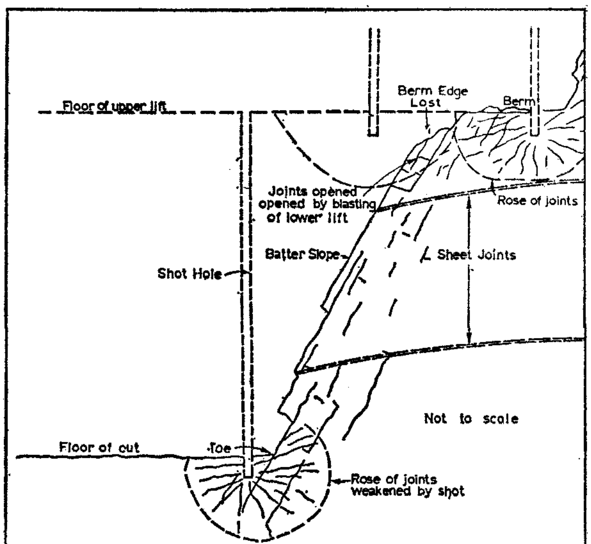

Figure 10: Shattering of toe of slope produced by overshooting and breakage of berm edge by two blasting cycles

At the Midland end of the cutting the 40-foot and 80-foot benches on the uphill side have been lost because of the highly broken and weathered nature of the wall rock, and also because of the particular methods used in excavating this end of the cutting.

Also at the Midland end of the cut, on the downhill side, the effects of open foliation joints have been accentuated by the presence of parallel bands of amphibolite, now highly weathered.

Rock expansion after compression

There appears to be a tendency for certain fractures or joint planes to become accentuated, and most of these features slope towards the bottom of the cut. It is possible that this is the result of elastic expansion of the gneiss towards available open space when the load is removed by excavation. The effect appears to be confined largely to rock where normal jointing is widely spaced.

Influence of water on rock cuttings

Water acts on a jointed rock mass to affect its engineering properties in three ways:

1. as pore water in the rock material itself
2. as pore water in joint filling material (this is sometimes called joint water)
3. as water contained in the joint spaces.

The effective strength of the rock is largely reduced by the pore water pressure in the rock and in the joint fillings. The water contained in the joints results in thrusts onto individual rock masses.

The joint volume in rock is small compared with that of the rock mass, and the rate of movement of water is slow. Water table fluctuations are large compared with variations in pervious sediments. Fig. 9 (after Long, 1964) shows that the wet and dry season water levels are distinct. However, run-off from heavy rain may reach towards the edge of the cutting in the area BC. Because this area is usually more stressed and broken, the joints tend to be more open. Consequently the run-off makes its way down into the rocks more readily than elsewhere; and the water table in the wedge ABC may rise temporarily to a position like AG. This added height of water exerts an added pressure, equal to the hydraulic head created, and this corresponds to the pore water pressure of soil mechanics, and may be called joint water pressure. If the rock near the toe of the slope is already stressed to near failure, the added joint water pressure may be sufficient to cause the slope to fail. For this reason diversion of surface water run-off should be provided for in the design, with raised diversion walls rather than excavated ditches being used to protect critical areas.

The position of the water table with regard to the boundary between highly weathered rock and fresher stronger rock is also a factor in slope stability. The weathered rocks may be impermeable because of infilling of joints, and pressure may develop that tends to move a large rock mass rather than a series of small separate blocks.

Sheet joints are favourably disposed to carry water, and the influence this has on rock weathering if profound (Gordon, 1966).

SLOPE APPRAISAL

A detailed geological diagram of the cutting is at present under production. Certain problems of slope stability have been considered separately from the broader geological problems in order that remedial works may be initiated, and these have been detailed (Gordon, 1966).

Types of slope failure.

The various types of slope failure can be grouped according to the nature of the movement and the material involved:

A. Rockfall—
- (1) because of closely spaced joints across cut
- (2) near shear or crush zones
- (3) at major joint intersections
- (4) because of overshot toes and relaxation into cut.

B. Block glide on sheet joints.

C. Debris falls—
- (1) on sheet joints as a mass
- (2) continuous frittering from weathered rock
- (3) from mechanically broken rock faces.

It is apparent that many of the above catagories are the result of a combination of several of the factors discussed in the previous section. For example closely spaced vertical joints, running obliquely across the cutting often allow excessive overbreak and overshooting of the toe. With oversteep faces largely stepped on joint planes, blocks of rock contained between the joints are often unsupported and fall (Plate 15A), the final trigger being often provided by stress relaxation (Plate 16B).

Several of the types of failure are shown in Plates 15 and 16, and these are described in full in the explanation of these figures.

General remedial measures

There is no doubt that a major cutting such as this, in rocks affected by chemical and physical weathering, will pose continuing maintenance problems. Fortunately ground water entry is mostly below the 40-foot bench, in rocks of reasonable mechanical condition.

It is expected that rainwash will continue to modify the slopes of highly weathered rocks at the Midland end of the cutting. It has previously been suggested that these slopes could be protected by grassing, but a grassing procedure would be an annual occurrence. What is needed to maintain many of the easily erodible cuts and fills on the Standard Gauge line is a plant form that the W.A.G.R. maintenance gangs would not feel impelled to burn off every year, and which would flourish in poor rocky conditions, while giving ample protection to the slope. As about 80% of the face in question on No. 2 Cut is formed in highly weathered rock with a recognisable rock texture, it is probable that slope control by botanical means would not be feasible, and the elimination of runnels is about the only work that is economically justified. The cost of continued maintenance and ditch clearing will certainly be large.

The 80-foot bench on the uphill wall is now no more than 5 feet wide, and the continued falling of debris has resulted in the bench being no longer an effective barrier to rock fall. If this bench is to be of some value for the cost of its construction, it should be cleared. Continued maintenance will then be needed. However, if clearing to full width involves digging away the toe of the batter above, then the project should be abandoned.

Investigation of deep rock cuttings

The experience of the investigation of the major cuttings in the Avon Valley Deviation, particularly Cut No. 2, has shown the need for an integrated study, rather than spasmodic or separate investigations by geologist, auger drilling for soils study, and diamond drilling. The following programme is considered optimum for the investigation of a deep rock cut:

1. Geological reconnaissance.
2. Joint survey for rock mechanics' appraisal.
3. Drill holes with auger drills to solid, and with air-track drills with experienced operators to full depth, geologist to log hole with operators assistance.
4. Open out top lift at maximum width to allow for flattest possible batter slope to bottom of cut.
5. Re-assess joint pattern revealed during excavation, and re-assess batter slopes of lower lifts.
6. Lay out shot holes and charges according to the exposures showing in the top lift.

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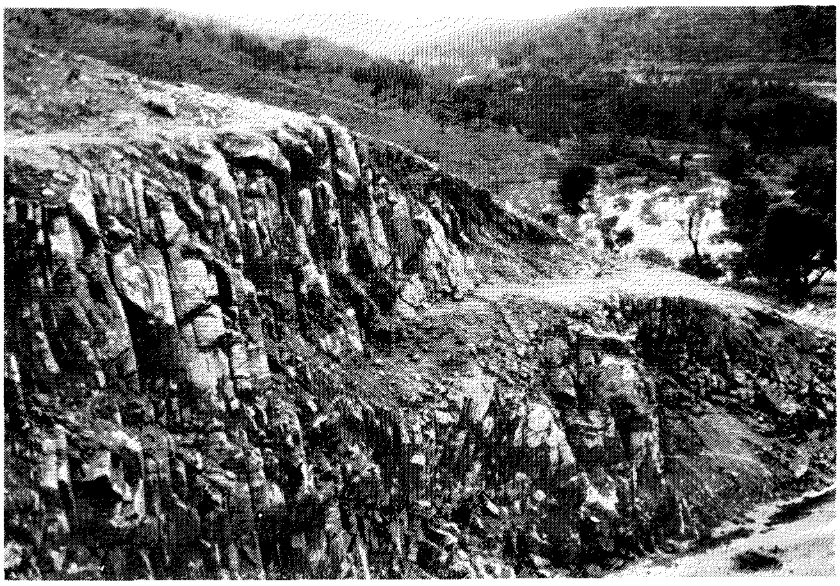
SEEPAGE PROBLEMS IN CUTTINGS IN THE UPPER AVON VALLEY, STANDARD GAUGE RAILWAY.

by F. R. Gordon

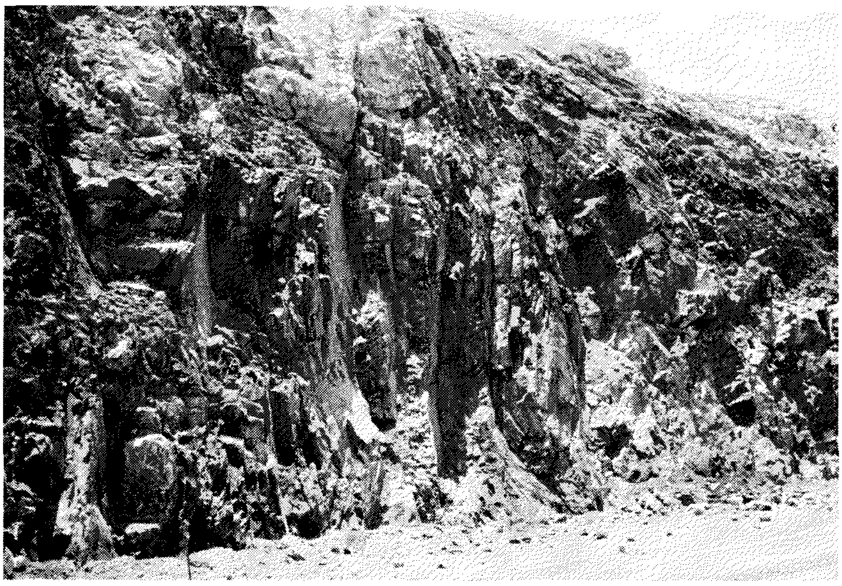
ABSTRACT

The construction of the Standard Gauge Railway through the valley of the Swan-Avon River system has revealed local geology in a unique fashion. Of particular interest has been the nature of the weathering profiles shown in different rock types, and the method of transmission of groundwater. Most of the cuttings between Montigap Brook and Northam had distinctive and often troublesome seepage patterns. A classification of the various types of water entry is of fundamental importance to any remedial works. One problem which is not resolved is the time taken for water entering the underground system on the ridges, to reach the various cuttings, most of which are situated about half way down the valley slope. Remedial works have been completed in most of the cuttings; further work is expected to be necessary in the major cuttings of Windmill Hill and Sewage Hill.


GEOLOGICAL SECTION THROUGH MT. CAMPBELL
Grey mudstone
Red sandstone
Grey mudstone
Serpulite band
Grey-brown sandstone
Pale mudstone
Pebble bed
Red & grey sandstone
Pale grey mudstone
Serpulite band
Red sandstone
Lenses of mudstone & pebbles
Mudstone lens
Pebble bed
Purple sandstone
White siltstone
Talus
Brown platy mudstone
FEET
Mount Campbell
Trig Point
Gogo Hill
Halls Creek (192m)
GREAT NORTHERN H'WAY
Fitzroy Crossing (8m)
Derby (178m)
START OF SEISMIC SURVEY
Mellenhole Creek
clay pan
approx. posn
approx. posns
Old Centre Line D.S.1 to D.S.3
Sandy Creek (new name)
FITZROY RIVER
Thin silt layer over sand
END OF SEISMIC SURVEY
Alligator Hill
Trig Point
GEOLOGICAL SECTION THROUGH ALLIGATOR HILL
Red sandstone
Coarse sandstone
Serpulite band
Pale-brown sandstone
Coarse sandstone
Serpulite band
White siltstone
White siltstone
Red sandstone
Brown sandstone
Brown sandstone
White siltstone
Red-brown sandstone
White siltstone
Red-brown sandstone
Brown platy mudstone
White siltstone
Clay & siltstone
PLAN REFERENCE
ALLUVIAL DEPOSITS RECENT
Grey - brown silt (soil)
Sands; medium to coarse grained
Gravel and cobbles
GRANT FORMATION PERMIAN
Bedded white siltstones and mudstones
Alternating red-brown sandstones and pale-grey mudstones
Brown platy mudstones
White siltstone and mudstone
Gemcodril hole drilled previous to 1965 showing depth of hole
Gemcodril hole drilled during 1965 showing depth to ? solid rock and index number
Pegged centre line
Geological boundary
Approximate geological boundary
Bedding dip & strike
D.S.1 Bench marks
A.1 1965 Survey control pegs
SECTION REFERENCE
RECENT
Grey brown silt (soil profile)
Alluvial brown silt
White siltstone ? reconsolidated weathering product N.B. This unit may be deeply weathered in-situ Grant Fmn.
Alluvial gravel and coarse sand
Alluvial sand, medium to fine grained
Alluvial sand coarse to very coarse grained
PERMIAN GRANT FORMATION
Alternating red-brown sandstone and pale-grey to white mudstone and siltstone
Natural surface
Geological boundary determined by drilling
Geological boundary determined by seismic investigation at this point
G.H. Gemcodril hole
P Projected position
D.S.3: AG. D.W.D.W.A. Survey stations
SCALE OF FEET
500 0 500 1000 1500 2000 2500
This map is based on aerial photos and is not to a precise or constant scale
Bend in Line
Bend in Line
RL
S.E.
N.W.
Mount Campbell
Alligator Hill
FITZROY RIVER
Possible second soil profile 30'-36'
GH 6
G.H.5p
G.H.16p
G.H.15p
G.H.18p
G.H.17
G.H.19
G.H.20
G.H.8p
G.H.11
GEOLOGICAL SURVEY OF WESTERN AUSTRALIA
GOGO DIVERSION DAM SITE
GEOLOGICAL PLAN AND SECTIONS
E.E. Swarbrick 1965

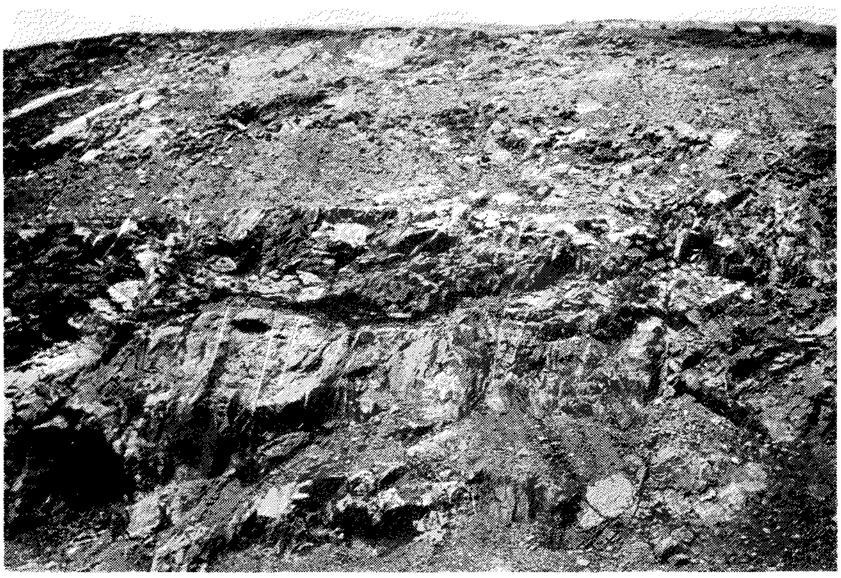


A—View of north wall at the Northam end of the cutting 22 miles 11 chains to 22 miles 13 chains, showing closely spaced foliation joints striking across the excavation. The rock type is a granite gneiss with some amphibolite dykes. (F887)

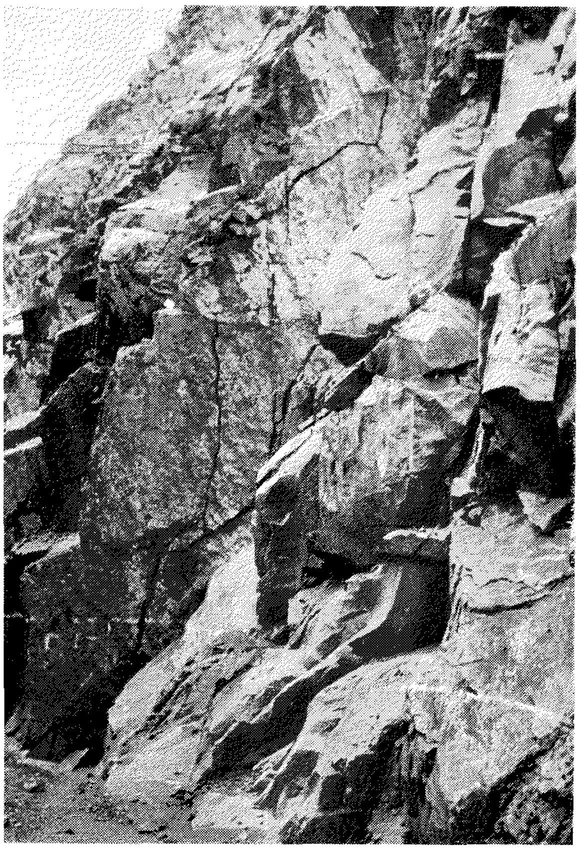


B—North wall between 22 miles 04 chains and 05 chains. Overshot toe has given an almost vertical face in folded, jointed and weathered amphibolite. Rock falls of minor size are to be expected with further weathering. Rafts of granite are notable. (F891)

C—North wall at 22 miles 07.25 chains. A shear zone 4 feet wide of augen schist coated with mica and talc flakes. Progressive frittering of the central core 1 foot wide will ultimately undermine the adjacent rock. (F892)



A—South wall, between 22 miles 02 chains and 04 chains. Highly weathered gneiss below the 40-foot bench is separated from moderately weathered rock by a sheet joint, dipping into the cut. The weathered rock is broken by clay filled joints and debris falls are expected if remedial works are not initiated. (F894)



B—South wall at 22 miles 12 chains. Widely spaced foliation joints have given large blocks of gneiss, and overbreak and later relaxation of blocks into the cut has produced a potential rockfall with at least five blocks involved. (F897)

INTRODUCTION

Between Northam and Toodyay the Avon River flows northwesterly in a wide mature valley which has a considerable thickness of alluvial and residual materials in the valley bottom. Between Toodyay and the Jimperding junction the valley is more constricted but the slopes are still gentle and the hills are subdued. The river enters a mature gorge near its junction with Montigap Brook, which takes the river, (there named the Swan) through the Darling Range, and provides the natural transportation route utilized by the Avon Valley Deviation of the Standard Gauge Railway.

Seepage problems were encountered in several of the railway cuttings between Montigap Brook and Northam and these are of interest from a hydrological as well as from an engineering view-point, as the movement of water is controlled in each case by distinct geological conditions.

GEOLOGICAL SETTINGS

The local rocks consist of foliated granite gneiss often containing considerable bodies of amphibolite, quartzite and schist that make up the Upper Jimperding Series of Prider (1944). These metamorphic rocks have been intruded by granite, pegmatite and aplite veins, and by quartz dolerite dykes.

The Avon River generally follows the structure of the rocks and near Windmill Hill and West Toodyay large swings of the valley faithfully reflect the folded pattern of easily eroded schist and amphibolite.

Most of the cuttings described are situated about half way up the gently sloping, left hand side of the valley. A minor range of hills of bare granite gneiss forms the crest of the valley wall, and a mantle of weathered rock descends to the river with an alluvial cover on the lower slopes. Erosion in the river valley has meant that the normal weathering sequence found on the gneissic rocks of the Darling Range (Gordon 1964a) is usually truncated. A vertical succession has been established for the local weathering profile:

Table 1

Material	Description
Soil, sand	Alluvial or residual
Laterite	Incomplete ferrugination, with a very mottled appearance of clay material
Gibbsite-kaolin	Yellow clay residual from completely weathered gneiss
Quartz-mica residual	Recognisable rock fabric, but most feldspars have been removed. Usually pervious and disintegrates into a sandy mass in water
Highly weathered gneiss	All mineral particles are present but are considerably altered. Pieces can be broken in the hand
Moderately weathered gneiss	Considerably weathered throughout but resists breaking in the hand
Slightly weathered gneiss	Limonite staining especially around joints, some cloudiness of feldspars
Fresh gneiss	Unweathered gneiss. Possible joint coatings include chlorite, calcite, pyrite and clay

SEEPAGE PROBLEMS AND CONDUITS

The seepage problems encountered in the various cuttings have been classified on the basis of the type of geological structure allowing water movement.

Sheet joints

Ainsworth cutting is situated on the normal gauge connection between the Great Southern Railway at Spencers Brook and the Standard Gauge marshalling yards west of Northam. The cut extends from 1 mile 40 chains to 2 miles 14 chains, with a maximum depth of 48 feet at 1 mile 66 chains.

The cutting is made in a highly foliated, banded granite gneiss, intruded by two dolerite dykes. The foliation strikes about 195 degrees, and dips at 45 degrees to the east, and this means that the foliation is running along most of the cutting. Although foliation is pronounced, the dominant structural feature is sheet jointing, generally parallel to the ground surface. Not only is the integrity of the rock mass broken, but groundwater movement has been controlled, thus dominating weathering (Gordon, 1966). This has resulted in considerable thicknesses of completely decomposed gneiss as clay, being found lying directly above relatively fresh gneiss, with the interface dipping from 15 degrees to 30 degrees towards the Avon River, i.e. to the east. A further consequence is that weathering around some of the deeper sheet joints has produced clay zones in the middle of fresh gneiss, dipping in conformity with the rock surface, towards the Avon River.

As a result, the excavation has exposed layers of weathered gneiss lying on sheet joints and dipping into the cutting on the uphill wall. In places the foliation dip coincides with the sheet joints, and the angle of dip is often close to the critical frictional angle (15 degrees for clay, 25 degrees for rock interfaces).

A major sheet joint about 33 feet above formation level at 1 mile 68 chains, and gently convex to meet formation level at 1 mile 72 chains, has caused the formation of two distinct layers of weathered rock. Fresh gneiss with limonite-stained joints occurs below the joint surface, and highly weathered to completely weathered gneiss above. The sheet joint dips into the cutting at angles from 10 degrees to 20 degrees and consists of a main fracture up to 2 inches thick, filled in places with clay, separated by 9 inches of highly weathered rock from another fracture zone up to 1 inch wide, and often filled with clay. The steeper dips are sufficient to allow block gliding into the cutting, and the onset of winter rains may cause pore water and joint water pressures to rise sufficiently to cause movement. There are ample vertical planes of potential separation provided by the quartz veinlets, running transversely to the cutting. At present a little water is emerging near 1 mile 69 chains and 1 mile 68.8 chains. Of particular interest is the section of cutting from 1 mile 69 chains to 1 mile 69.5 chains, where clean separation of the upper and lower surfaces of the sheet joint implies some degree of movement.

In addition to the potential glide plane provided by the sheet joint zone, a 10 foot high overhanging "back" has developed on this surface between 1 mile 69.2 chains and 1 mile 70.3 chains. This has developed on a locally prominent joint that dips from 50 degrees to 70 degrees away from the cutting, and overbreak on this during construction has been emphasised by later falls. Water seepage, along with rock materials and the situation, is the cause of movement (see Plate 17A).

Foliation joints

Migrant Hill cutting extends from 73 miles 45 chains to 74 miles 06 chains with a maximum depth of cut of no more than 14 feet. The peak of a verticle curve is at 73 miles 72 chains, and the fall in either direction is 1 in 1,172. Because of superelevation required by a horizontal curve, the lowest section in the cutting is at the toe of the uphill batter slope. The excavation of the cut had been completed, and fill material spread on the floor to reach formation level, when entry of water caused saturation and heaving (under traffic) of the subbase fill. A ditch, cut along the foot of the uphill batter, immediately became full of water.

The cutting exposes weathered, banded gneiss, and the absence of a laterite sequence indicates that the upper layers of the weathering profile have been removed by river erosion. The material in the cutting walls is moderately to slightly weathered gneiss. Strong foliation strikes along the cut at the Toodyay end and obliquely across the cutting at the Northam end, with a dip to the east of 40 degrees. The only open joint system is along the numerous foliation planes, and in the upper 20 feet of the sequence these are filled with clay minerals. The cut has exposed significant openings below this. Heaving was confined to the uphill side and middle portion of the cutting floor, showing that water has direct access into the joints below formation level, and rises to the floor of the cutting.

The use of formation material that is devoid of fines, and the use of a pervious blanket in the subbase, were suggested to stabilize the cutting floor. Entry of water was still unrestricted however, and continuous saturation of clay areas would have allowed water to work through the subbase and cause heaving.

The solution was a ditch deep enough to intersect the open joints that carry water into and through the rock floor. This involved an excavation 3½ feet deep, with its bottom and downhill side coated with a bituminous layer to prevent further water movement. Evaporation in the summer months may be sufficient to maintain a reasonably low water level, and gravity drainage from the ends allows the removal of surplus water.

The amount of water entering through the slopes and floor of the cut varies seasonally, and conditions are at their worst late in winter and in early spring.

Variations in rock type

The cutting at Sewage Hill extends from 72 miles 10 chains to 73 miles 35 chains, and has a downward grade of 1 in 1,650 in either direction from its mid-point. It will carry both standard gauge and normal gauge tracks, which diverge at each end of the cutting, so that the bifurcation is within the cutting.

After the rock excavation was completed with a maximum of 35 feet of cut at 72 miles 26 chains, large quantities of water emerged in the floor and uphill side of the excavation at either end and saturated the subbase. As a precaution a sand blanket 2 feet thick was spread over the cut floor, with a subbase placed on top, raising the formation level. The horizontal curve of the cutting makes the lowest section lie along the toe of the uphill batter slope.

At the Toodyay end, the area between the two diverging tracks was about 4 feet deeper than formation level, and in this triangle a considerable amount of water accumulated from seepage. In one place a mud heave about 10 feet by 10 feet displaced 2 feet of the narrow gauge embankment. Water emerged from the centre of the heave, which was situated in an area of soft, saturated clays. Another mud heave was close to the standard gauge track. The cutting here is about 12 feet high in partially decomposed granite gneiss showing very strong foliation and banding at 045 degrees strike and 70 degrees dip to the east. The most prominent features of the banding are amphibolite bands several feet thick, sometimes bounded by fault zones, and these amphibolites are apparently connected with the two areas of mud heaving. Water is lying in the ditch at the foot of the hillside batter, and as the bottom of the ditch is not consolidated, the adjacent sand blanket and about 1 foot of the subbase are saturated.

The water moves along the joint systems, but bands of amphibolite in the gneiss are major collectors because of large scale breakage along minor joints, and the deeper weathering of this rock type in comparison with the adjacent gneiss, means that the open joints are below formation level, and are not controlled by the side drains. It was considered that the sand blanket would collect much of the subsurface water but would gradually saturate, and allow saturation of the formation. The use of a blanket thus allowed construction to proceed but only postponed the difficulty.

Certain remedial works were initiated, and part of the interformational area was filled in with quarry run rock. The ditches on either side of the cutting were deepened to about 2½ feet and were protected by concrete box flume sections. However, probing revealed that the mud boil which progressively threatened the standard gauge embankment was connected with a depression 4 feet deeper than the surrounding firm rock surface. This proved to be the result of deeper weathering in the amphibolite band already referred to. To control and divert the entry of water, it was recommended that relief wells should be drilled along the toe of the uphill wall. Further, the depressed area through the standard gauge embankment should be dug out and replaced with crusher dust. Finally the drainage of the lower apex area between the tracks should be lowered by deepening the ditches leading from this area.

Quartz veins

A major cutting occurs to the west of the junction of Jimperding Brook with the Avon River, where a broad spur descending from rugged uplands has caused a considerable curve in river direction. The railway line is in a cutting from 49 miles 14 chains to 49 miles 48 chains with a maximum depth of cut of 25 feet at 49 miles 31 chains. A horizontal curve of 40 chains radius and a vertical curve of 10 chains radius (I.P. at 49 miles 35 chains) means that the toe of the uphill (inside) batter is the lowest part of the cross section, and although the cutting drains in two directions, the fall is small. In 1964 after completion of excavation, large quantities of water emerged from the uphill batter during the winter months, and saturated the subbase material. Seepage from the toe of the slopes in the floor of the cut continued to keep the foundation filling soft and liable to heave under traffic.

Most of the cutting is in highly to moderately weathered amphibolite, which forms large lenticular masses, parallel to the foliation in the granite gneiss, and elongated and laminated parallel to the strike. The amphibolite enclosures are traversed by small quartz veins, and have been intruded by the granite, which occurs in sills and pinnacles. The schistosity of the amphibolite strikes about 090 degrees and dips about 30 degrees to the north, i.e. into the cutting from the uphill side.

When the cutting was examined in January, 1965, plants and grasses were growing freely on the areas of maximum water entry, and also where springs occur in the floor of the cut. The springs and high seepage areas coincided with the positions of quartzose veins in the amphibolite as the highly jointed quartz allowed more freedom of movement to water than the amphibolite, in which the joints were largely filled with weathering products. However in the amphibolites there is a general "background" flow from down the schistosity surfaces and minor sheet joints which are nearly coincident.

The amphibolite is quite friable and frets continually, and the low grades mean that even minor blockage of the drain would cause a build up of water over a large area.

The subbase, which became unstable when saturated, consisted of weathered amphibolite, the schistose nature of the particles and the high degree of weathering combining to produce a weak fill material when wet.

Remedial measures included (1) deepening and cleaning out the ditch and covering it with concrete box sections with removable lids; (2) digging out the subbase in the wet areas and replacing with better grade rock rubble; and (3) emplacing subsoil drains on the rock floor in areas where the quartz veins carrying water crossed the cut and gave rise to springs. (See Plate 17B).

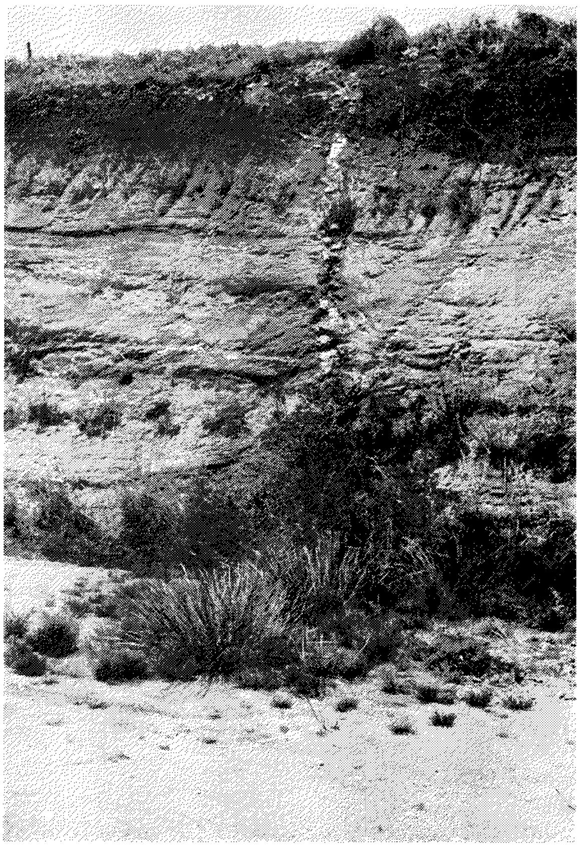
Bedding joints

The cutting at Windmill Hill extends from 61 miles 16.5 chains to 61 miles 39.2 chains with a maximum depth of cut of 95 feet on the centre line at 61 miles 26.5 chains. It has been the scene of intensive geological examination as two rockslides have taken place in a band of schist enclosed in quartzites (Gordon, 1963 and 1964). During the investigation of the first slide, diamond drilling revealed some aspects of the movement of groundwater, and this is bound up with the long term stability of the cutting. The quartzites strike across the cutting direction, and the well defined bedding planes dip at about 45 degrees to the Northam end.

During the excavation of the cutting, groundwater was encountered at about 15 feet above formation level in well bedded quartzite as the lowest lift was

A—Overhang at 1 mile 69.5 chains. The highly to completely weathered gneiss, collapsing into the cutting on the sheet joint surface, is defined by joints striking in the same direction as the sheet joints, and dipping at right angles to it. Seepage on main sheet joint initiating movement.

(F901)



B—Uphill batter of cutting west of Jimperding Brook at 49 miles 22.2 chains showing completely weathered to highly weathered amphibolite traversed by a quartz vein 9 inches wide which has caused a spring to develop in the floor of the cutting.

(F1015)

advanced towards Northam. At 61 miles 23 chains a structural terrace of biotite and tremolite-biotite schist occurred, saturated as high as 30 feet above formation level, and the presence and action of water was one of the main factors in causing the rockslide that commenced on 29th. April, 1963. Excavation was stopped and diamond drilling from the top of the lower lift (30 feet above formation) intersected pressure water that flowed from two boreholes, in quartzite immediately before they passed into the schist. This showed that the highly weathered schist was acting as a barrier to water moving relatively freely in the numerous open bedding joints of the quartzite. With the completion of excavation, the groundwater level subsequently dropped to formation level. It is expected that groundwater level variations will be seasonal, but the most important aspect is that the mica schist below formation level will be liable to saturation. Although the area of rock fall has been temporarily stabilized by reduction of slope, it is noted that the additional recommended remedial measures of subsurface drainage, subhorizontal drain holes, and strutting across the cut floor have not been implemented.

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THE SEARCH FOR OIL IN WESTERN AUSTRALIA IN 1965

by P. E. Playford

INTRODUCTION

Oil exploration in Western Australia continued to expand during 1965. Exploration was carried out in all sedimentary basins except the Ord Basin. A record number of 26 test wells and 10 stratigraphic wells were completed, 1 test well was suspended, and a further 3 test wells and 1 stratigraphic well were drilling at the end of the year. Of the test wells, 17 were completed as potential oil or gas producers: Barrow Nos. 4-17 (oil or gas or both) in the Carnarvon Basin, and Gingin No. 1 (gas and condensate), Mt. Horner No. 1 (oil), and Arrowsmith No. 1 (gas) in the Perth Basin.

Seismic operations increased sharply from 60 party months in 1964 to 93 party months in 1965, but gravity surveys fell from 39 to 14 party months. Aeromagnetic surveys totalling some 44,000 line miles were flown in 1965, whereas none were flown the previous year. Field geological surveys amounted to 16 geologist months in 1965, compared with 44 geologist months in 1964.

OIL HOLDINGS

The positions of permits to explore and licenses to prospect in Western Australia at the end of 1965 are shown on Plate 18. The number of permits was less than in the previous year owing to the relinquishment or cancellation of some in unprospective areas. Details of each concession current at the end of the year are as follows:

OIL HOLDINGS IN WESTERN AUSTRALIA ON 31st DECEMBER 1965

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 (Renewal applied for)
28H	do. do. do.	30,750	31/12/65 (Renewal applied for)
30H	do. do. do.	140,200	31/12/65 (Renewal applied for)
106H	Westralian Oil Limited	11,800	28/3/66
127H	Alliance Oil Development Australia N.L.	13,800	28/3/66
134H	Exoil Pty. Ltd. and Hunt Petroleum Corporation	12,600	9/12/65 (Renewal applied for)
135H	do. do. do.	12,600	9/12/65 (Renewal applied for)
136H	do. do. do.	12,450	9/12/65 (Renewal applied for)
147H	Hunt Oil Co. and Placid Oil Co.	12,850	16/8/66
148H	do. do. do.	12,600	16/8/66
151H	Beach-General Exploration Pty. Ltd.	14,200	7/2/66
152H	do. do. do.	11,650	7/2/66
153H	do. do. do.	13,050	7/2/66
156H	Hunt Oil Co. and Placid Oil Co.	12,450	10/7/66
157H	do. do. do.	12,600	10/7/66
158H	do. do. do.	12,800	10/7/66
159H	do. do. do.	12,800	10/7/66
161H	do. do. do.	12,900	24/8/66
172H	Alliance Petroleum Australia N.L.	6,150	30/3/66
173H	do. do. do.	12,250	30/3/66
174H	do. do. do.	6,100	30/3/66
175H	do. do. do.	6,050	30/3/66
177H	do. do. do.	6,050	30/3/66
193H	Hawkstone Oil Co. Ltd.; BP Petroleum Development Australia Pty. Ltd.	2,750	5/2/66
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	28/2/66
210H	do. do.	12,100	28/2/66
213H	Woodside (Lakes Entrance) Oil Co. N.L.; B.O.C. of Aust. Ltd.; Shell Development (Aust.) Pty. Ltd.	104,000	20/6/66
217H	West Australian Petroleum Pty. Ltd.	17,600	30/5/66
221H	Australian Aquitaine Petroleum Pty. Limited; Arco Ltd.	44,000	28/7/66
225H	West Australian Petroleum Pty. Ltd.	8,000	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
232H	Victorian Oil No Liability	3,000	10/9/66
233H	West Australian Petroleum Pty. Ltd.	6,800	10/2/67
235H	Tasman Oil Pty. Ltd.	19,400	21/1/67
236H	Abrolhos Oil No Liability; BP Petroleum Development Australia Pty. Ltd.	2,600	3/2/67
237H	West Australian Petroleum Pty. Ltd.	8,950	Appln. pending
238H	B.O.C. of Australia Ltd.; Shell Development (Aust.) Pty. Ltd.; Woodside (Lakes Entrance) Oil Co. N.L.	1,220	do.
239H	Abrolhos Oil No Liability	5,200	do.

LICENSES TO PROSPECT

No.	Name of Holder	Area in Square Miles	Date of Expiry of Current Tenure
87H	West Australian Petroleum Pty. Ltd.	188·973	5/1/66
90H	do. do. do.	160·520	27/2/66
91H	do. do. do.	133·841	27/2/66
94H	do. do. do.	186·473	27/2/66
96H	do. do. do.	100	18/3/66
97H	do. do. do.	191·396	26/7/66
99H	do. do. do.	190·458	4/12/66
101H	do. do. do.	193·620	17/12/66
102H	do. do. do.	195·551	13/1/66
103H	do. do. do.	200	20/5/66
104H	do. do. do.	197·867	6/6/66
105H	do. do. do.	196·032	14/8/66
106H	do. do. do.	200	11/9/66
107H	do. do. do.	200	25/2/66
108H	do. do. do.	200 (excluding Lyndon Loc. 42)	22/1/66
109H	do. do. do.	200	22/2/66
111H	do. do. do.	150	4/6/66
113H	do. do. do.	200	10/5/66
114H	Alliance Oil Development Aust. N.L.	67	27/10/66
115H	West Australian Petroleum Pty. Ltd.	200	5/11/66
117H	do. do. do.	200	10/9/66
118H	do. do. do.	117·687	29/9/66
119H	do. do. do.	109·032	12/1/67
120H	Westralian Oil Limited	195·984	30/11/66
121H	Associated Freney Oil Fields N.L.	120	11/7/67
122H	do. do. do.	113·418	11/7/67
123H	do. do. do.	113·232	11/7/67
124H	do. do. do.	112·528	20/4/67
125H	do. do. do.	112·477	20/4/67
126H	West Australian Petroleum Pty. Ltd.	200	8/2/67
127H	do. do. do.	200	17/1/67
128H	do. do. do.	182	8/3/67
129H	do. do. do.	200	8/3/67
130H	do. do. do.	189·929	28/3/67
132H	do. do. do.	200	13/5/67

No.	Name of Holder	Area in Square Miles	Date of Expiry of Current Tenure
133H	do. do. do.	200	13/5/67
134H	do. do. do.	199·437	20/4/67
135H	do. do. do.	186·012	17/5/67
136H	do. do. do.	190·765	17/5/67
137H	do. do. do.	192·889	17/5/67
138H	do. do. do.	196·224	17/5/67
139H	do. do. do.	189·684	17/5/67
140H	do. do. do.	198·750	17/5/67
141H	do. do. do.	188·941	17/5/67
142H	do. do. do.	193·350	17/5/67
143H	do. do. do.	198·133	17/5/67
144H	do. do. do.	193·104	17/5/67
145H	do. do. do.	187·411	17/5/67
146H	do. do. do.	187·032	17/5/67
147H	do. do. do.	188·953	17/5/67
148H	do. do. do.	200	9/6/67
149H	do. do. do.	200	14/7/67
150H	do. do. do.	200	18/10/67
151H	do. do. do.	194·376	5/7/67
152H	do. do. do.	192	18/10/67
153H	do. do. do.	196	18/10/67
154H	Beach-General Exploration Pty. Ltd.	160·20	13/12/67
155H	West Australian Petroleum Pty. Ltd.	193·75	18/10/67
156H	do. do. do.	200	Appln. pending
157H	do. do. do.	193	do.

DRILLING

The positions of all wells drilled for petroleum exploration in Western Australia to the end of 1965 are shown on Plate 19. The following wells were drilled during the year:

PERMIT TO EXPLORE 27H

Permit to Explore 27H is held by West Australian Petroleum Pty. Ltd. and covers part of the Perth Basin. The company completed 7 test wells (Allanooka Nos. 1 and 2, Eurangoa No. 1, Gingin No. 1, Mt. Horner Nos. 1 and 2 and Pinjarra No. 1) and 6 stratigraphic wells (Alexandra Bridge No. 1, Bookara No. 1, and Mungarra Nos. 2-5) during 1965. One test well (Gingin No. 2) was awaiting completion at the end of the year.

Allanooka No. 1

Type: Oil test.
License to Prospect: 119H.
Latitude and Longitude: 28° 08′ 31″ S., 115° 00′ 40″ E.
Elevation: Ground level 153 feet, rotary table 166 feet.
Date commenced: 8th January, 1965.
Date completed: 26th January, 1965.
Total depth: 3,895 feet.
Bottomed in: Lower Permian.
Remarks: Dry and abandoned.

Allanooka No. 2

Type: Oil test.
License to Prospect: 119H.
Latitude and Longitude: 29° 06′ 00″ S., 114° 59′ 36″ E.
Elevation: Ground level 218 feet, rotary table 231 feet.
Date commenced: 3rd February, 1965.
Date completed: 13th February, 1965.
Total depth: 3,300 feet.
Bottomed in: Precambrian.
Remarks: Dry and abandoned.

Eurangoa No. 1

Type: Oil test.
License to Prospect: 126H.
Latitude and Longitude: 29° 07′ 34″ S., 115° 08′ 10″ E.
Elevation: Ground level 813 feet, rotary table 826 feet.
Date commenced: 14th June, 1965.
Date completed: 9th July, 1965.
Total depth: 7,470 feet.
Bottomed in: Lower Permian.
Status: Dry and abandoned.

Gingin No. 1

Type: Oil test.
License to Prospect: 115H.
Latitude and Longitude: 31° 08′ 32″ S., 115° 49′ 35″ E.
Elevation: Ground level 649 feet, rotary table 665 feet.
Date commenced: 16th November, 1964.
Date completed: 14th July, 1965.
Total depth: 14,908 feet.
Bottomed in: Lower Jurassic.
Status: Oil and condensate well, completed over the intervals 12,680-12,728 and 12,956-12,998 feet in the Cockleshell Gully Formation. The following are the results of some of the more important tests: Interval 13,620-13,630 feet gave 3.39 million cubic feet of gas, 73.2 barrels of condensate (46° A.P.I.) and 37.4 barrels of water per day. Interval 13,278-13,296 feet gave 3.84 million cubic feet of gas, 47 barrels of condensate, and 10 barrels of water per day. Combined intervals 12,700-12,709 feet, 12,712-12,718, and 12,722-12,728 feet gave 3.74 million cubic feet of gas, 34.64 barrels of condensate, and 8.76 barrels of water per day.

Gingin No. 2

Type: Oil test.
License to Prospect: 115H.
Latitude and Longitude: 31° 10′ 08″ S., 115° 50′ 35″ E.
Elevation: Ground level 856 feet, rotary table 872 feet.
Date commenced: 25th July, 1965.
Status: Testing on 31st December, total depth 14,704 feet.

Mt. Horner No. 1

Type: Oil test.
License to Prospect: 126H.
Latitude and Longitude: 29° 07′ 42″ S., 115° 05′ 00″ E.
Elevation: Ground level 642 feet, rotary table 655 feet.
Date commenced: 26th February, 1965.
Date completed: 17th April, 1965.
Total depth: 7,390 feet.
Bottomed in: Lower Permian.
Status: Oil well, completed over the interval 4,834-4,896 feet. Swabbing of the interval 4,870-4,890 feet produced 80 barrels of oil-water emulsion. Further pump tests are in progress to evaluate the production potential of the well.

Mt. Horner No. 2

Type: Oil test.
License to Prospect: 111H.
Latitude and Longitude: 29° 08′ 41″ S., 115° 04′ 34″ E.
Elevation: Ground level 496 feet, rotary table 508 feet.
Date commenced: 24th April, 1965.
Date completed: 27th May, 1965.
Total depth: 6,746.
Bottomed in: Lower Permian.
Status: Dry and abandoned.

Pinjarra No. 1.

Type: Oil test.
License to Prospect: 128H.
Latitude and Longitude: 32° 40′ 38″ S., 115° 45′ 10″ E.
Elevation: Ground level 18 feet, kelly bushing 34 feet.
Date commenced: 5th October, 1965.
Date completed: 31st December, 1965.
Total depth: 15,001 feet.
Bottomed in: Upper Triassic.
Remarks: Dry and abandoned.

Alexandra Bridge No. 1

Type: Oil test.
Latitude and Longitude: 34° 09′ 35″ S., 115° 15′ 33″ E.
Elevation: Ground level 123 feet, derrick floor 128 feet.
Date commenced: 27th July, 1965.
Date completed: 10th August, 1965.
Total depth: 2,513 feet.
Bottomed in: Upper Permian.
Status: Dry and abandoned.

Bookara No. 1

Type: Stratigraphic.
Latitude and Longitude: 28° 59′ 28″ S., 114° 45′ 50″ E.
Elevation: Ground level 65 feet, derrick floor 70 feet.
Date commenced: 23rd April, 1965.
Date completed: 29th April, 1965.
Total depth: 926 feet.
Bottomed in: Precambrian.
Status: Dry and abandoned.

Mungarra No. 2

Type: Stratigraphic.
License to Prospect: 119H.
Latitude and Longitude: 28° 54′ 30″ S., 115° 04′ 54″ E.
Elevation: Ground level 762 feet, rotary table 767 feet.
Date commenced: 25th January, 1965.
Date completed: 10th February, 1965.
Total depth: 2,010 feet.
Bottomed in: Lower Permian.
Status: Dry and abandoned.

Mungarra No. 3

Type: Stratigraphic.
Latitude and Longitude: 28° 57′ 52″ S., 115° 04′ 53″ E.
Elevation: Ground level 808 feet, derrick floor 813 feet.
Date commenced: 9th March, 1965.
Date completed: 29th March, 1965.
Total depth: 2,070 feet.
Bottomed in: Lower Triassic.
Status: Dry and abandoned.

Mungarra No. 4.

Type: Stratigraphic.
Latitude and Longitude: 28° 54′ 15″ S., 115° 15′ 50″ E.
Elevation: Ground level 861 feet, derrick floor 866 feet.
Date commenced: 16th June, 1965.
Date completed: 30th June, 1965.
Total depth: 2,110 feet.
Bottomed in: Upper Jurassic.
Remarks: Dry and abandoned.

Mungarra No. 5

Type: Stratigraphic.
Latitude and Longitude: 28° 54′ 40″ S., 115° 08′ 03″ E.
Elevation: Ground level 765 feet, derrick floor 770 feet.
Date commenced: 30th June, 1965.
Date completed: 10th July, 1965.
Total depth: 2,040 feet.
Bottomed in: Lower Permian.
Remarks: Dry and abandoned.

PERMIT TO EXPLORE 30H

Permit to Explore 30H is held by West Australian Petroleum Pty. Ltd. During 1965 the company drilled 3 wells in this permit area, two of which (Parda No. 1 and Willara No. 1) were abandoned as dry holes, and the other (Sahara No. 1) was suspended for possible deepening in the future. Another well (Kidson No. 1) was still drilling at the end of the year.

Kidson No. 1

Type: Oil test.
License to Prospect: 155H.
Latitude and Longitude: 22° 37′ 00″ S., 125° 00′ 22″ E.
Elevation: Ground level 1,165 feet, rotary table 1,181 feet.
Date commenced: 21st November, 1965.
Status: Drilling ahead at 7,269 feet on 31st December.

Parda No. 1

Type: Oil test.
License to Prospect: 129H
Latitude and Longitude: 18° 56′ 08″ S., 122° 00′ 34″ E.
Elevation: Ground level 335 feet, derrick floor 351 feet.
Date commenced: 19th April, 1965.
Date completed: 17th May, 1965.
Total depth: 6,256 feet.
Bottomed in: Precambrian.
Status: Dry and abandoned.

Sahara No. 1

Type: Oil test.
License to Prospect: 117H.
Latitude and Longitude: 21° 04′ 40″ S., 123° 23′ 30″ E.
Elevation: Ground level 868 feet, derrick floor 884 feet.
Date commenced: 11th January, 1965.
Date completed: 3rd March, 1965.
Total depth: 6,956 feet.
Bottomed in: Evaporite sequence, Lower Devonian or older.
Status: Suspended for possible deepening.

Willara No. 1

Type: Oil test.
License to Prospect: 148H.
Latitude and Longitude: 19° 10′ 48″ S., 122° 04′ 14″ E.
Elevation: Ground level 249 feet, derrick floor 265 feet.
Date commenced: 9th June, 1965.
Date completed: 18th October, 1965.
Total depth: 12,806 feet.
Bottomed in: Lower Ordovician.
Status: Dry and abandoned.

PERMIT TO EXPLORE 134H

Permit to Explore 134H is held by Exoil Pty. Ltd. and Hunt Petroleum Corporation. Hunt Oil Co. acts as operator for the permit. One stratigraphic hole (Lennis No. 1) was drilled during the year.

Lennis No. 1.

Type: Stratigraphic.
Latitude and Longitude: 27° 17′ S., 126° 21′ E.
Elevation: Ground level 1,362 feet, kelly bushing 1,367 feet.
Date commenced: 29th September, 1965.
Date completed: 8th October, 1965.
Total depth: 2,016 feet.
Status: Dry and abandoned.

PERMIT TO EXPLORE 147H

Permit to Explore 147H is held by Hunt Oil Co. and Placid Oil Co., Hunt being the operator. The company drilled three stratigraphic wells (Browne Nos. 1 and 2 and Yowalga No. 1) in this permit during 1965.

Browne No. 1

Type: Stratigraphic.
Latitude and Longitude: 25° 51′ S., 125° 49′ E.
Elevation: Ground level 1,489 feet, kelly bushing 1,494 feet.
Date commenced: 6th September, 1965.
Date completed: 15th September, 1965.
Total depth: 1,269 feet.
Status: Dry and abandoned.

Browne No. 2

Type: Stratigraphic.
Latitude and Longitude: 25° 56′ S., 125° 58′ E.
Elevation: Ground level 1,588 feet, kelly bushing 1,593 feet.
Date commenced: 13th October, 1965.
Date completed: 19th October, 1965.
Total depth: 960 feet.
Status: Dry and abandoned.

Yowalga No. 1

Type: Stratigraphic.
Latitude and Longitude: 26° 11′ S., 125° 58′ E.
Elevation: Ground level 1,554 feet, kelly bushing 1,559 feet.
Date commenced: 16th September, 1965.
Date completed: 19th September, 1965.
Total depth: 2,011 feet.
Status: Dry and abandoned.

PERMIT TO EXPLORE 151H

Permit to Explore 151H is held by Hackathorn Oils Pty. Ltd. and has been farmed out to Australian Aquitaine Petroleum Pty. Ltd. and Beach Petroleum N.L., Australian Aquitaine being the operator. The company began drilling a stratigraphic well, Point Moody No. 1, in the permit area during 1965.

Point Moody No. 1

Type: Stratigraphic.
License to Prospect: 154H.
Latitude and Longitude: 21° 15′ 34″ S., 127° 48′ 22″ E.
Elevation: Ground level 1,387 feet, rotary table 1,400 feet (approx.).
Date commenced: 1st October, 1965.
Status: Drilling ahead at 7,535 feet on December 31st.

PERMIT TO EXPLORE 217H

Drilling on this permit, which is held by West Australian Petroleum Pty. Ltd. was confined to Barrow Island, where 15 test wells were completed during the year. Of these, all except the last (Barrow No. 18) were completed as potential producing wells. Three oil and gas wells had been completed in the previous year.

Four producing horizons have now been established on the island. The shallowest of these occurs as thin sands of low permeability in the Lower Cretaceous Windalia Radiolarite, at depths (subsea) ranging from —1,834 feet in Barrow No. 4 to —2,475 feet in Barrow No. 9. Eleven wells have been completed as potential producers from the Windalia (Barrow Nos. 4, 5, and 9-17). The other three producing horizons are sands in the Jurassic sequence at depths of about 6,200 feet (Barrow No. 2), 6,600 feet (Barrow No. 7) and 6,700 feet (Barrow Nos. 1, 3, 6 and 8). Oil production from tests in the Windalia sands averages about 150 barrels per day with variable amounts of gas, reaching as high as a million cubic feet per day in one well. The Jurassic sands are more productive, ranging from 230 to 980 barrels of oil per day. The maximum flow of gas recorded from the Jurassic is 11 million cubic feet per day, but in the completed intervals the maximum flow is 1.9 million cubic feet per day. Barrow No. 7 is the only well completed in the Jurassic which did not yield gas.

Barrow No. 4

Type: Oil test.
License to Prospect: 113H.
Latitude and Longitude: 20° 50′ 32″ S., 115° 23′ 05″ E.
Elevation: Ground level 101 feet, derrick floor 112 feet.
Date commenced: December 15th, 1964.
Date completed: February 6th, 1965.
Total depth: 7,816 feet.
Bottomed in: Upper Jurassic.
Status: Oil and gas well, completed over the interval 1,946-1,958 feet in the Windalia Radiolarite.

Barrow No. 5

Type: Oil test.
License to Prospect: 113H.
Latitude and Longitude: 20° 48′ 03″ S., 115° 23′ 40″ E.
Elevation: Ground level 216 feet, rotary table 227 feet.
Date commenced: 12th February, 1965.
Date completed: 27th March, 1965.
Total depth: 7,390 feet.
Bottomed in: Upper Jurassic.
Status: Gas well, completed over the intervals 2,210-2,230, 2,235-2,245, 2,270-2,276 and 2,291-2,297 feet in the Windalia Radiolarite.

Barrow No. 6

Type: Oil test.
License to Prospect: 113H.
Latitude and Longitude: 20° 48′ 55″ S., 115° 23′ 40″ E.
Elevation: Ground level 202 feet, rotary table 213 feet.
Date commenced: 1st April, 1965.
Date completed: 12th May, 1965.
Total depth: 7,726 feet.
Bottomed in: Upper Jurassic.
Status: Oil and gas well completed over the interval 6,800-6,820 feet in Jurassic sediments.

Barrow No. 7

Type: Oil test.
License to Prospect: 113H.
Latitude and Longitude: 20° 43′ 58″ S., 115° 25′ 25″ E.
Elevation: Ground level 150 feet, derrick floor 161 feet.
Date commenced: 18th May, 1965.
Date completed: 2nd July, 1965.
Total depth: 8,002 feet.
Bottomed in: Upper Jurassic.
Status: Oil well, completed over the interval 6,590-6,600 feet in the Windalia Radiolarite.

Barrow No. 8

Type: Oil well.
License to Prospect: 113H.
Latitude and Longitude: 20° 48′ 58″ S., 115° 23′ 53″E.
Elevation: Ground level 209 feet, rotary table 220 feet.
Date commenced: 8th July, 1965.
Date completed: 11th August, 1965.
Total depth: 7,401 feet.
Bottomed in: Upper Jurassic.
Status: Oil and gas well, completed over the interval 6,808-6,820 feet in Jurassic sediments.

Barrow No. 9

Type: Oil test.
License to prospect: 113H.
Latitude and Longitude: 20° 51′ 38″ S., 115° 24′ 55 E.″
Elevation: Ground level 46 feet, rotary table 57 feet.
Date commenced: 18th August, 1965.
Date completed: 23rd September, 1965.
Total depth: 7,981 feet.
Bottomed in: Upper Jurassic.
Status: Oil and gas well, completed over the intervals 2,562-2,574 feet and 2,578-2,590 feet in the Windalia Radiolarite.

Barrow No. 10

Type: Oil test.
License to Prospect: 113H.
Latitude and Longitude: 20° 49′ 54″ S., 115° 24′ 50″ E.
Elevation: Ground level 118 feet, rotary table 129 feet.
Date commenced: 25th September, 1965.
Date completed: 8th October, 1965.
Total depth: 2,460 feet.
Bottomed in: Lower Cretaceous.
Status: Oil well, completed over the interval 2,258-2,273 feet in the Windalia Radiolarite.

Barrow No. 11

Type: Oil test.
License to Prospect: 113H.
Latitude and Longitude: 20° 50′ 43″ S., 115° 22′ 30″ E.
Elevation: Ground level 113 feet, rotary table 124 feet.
Date commenced: 10th October, 1965.
Date completed: 29th October, 1965.
Total depth: 2,281 feet.
Bottomed in: Lower Cretaceous.
Status: Oil well, completed over the interval 2,003-2,021 feet in the Windalia Radiolarite.

Barrow No. 12

Type: Oil test.
License to Prospect: 113H.
Latitude and Longitude: 20° 48′ 58″ S., 115° 24′ 49″ E.
Elevation: Ground level 164 feet, rotary table 175 feet.
Date commenced: 22nd October, 1965.
Date completed: 31st October, 1965.
Total depth: 2,564 feet.
Bottomed in: Lower Cretaceous.
Status: Oil well, completed over the intervals 2,262-2,272 feet, 2,280-2,285 feet, 2,292-2,302, and 2,343-2,349 feet in the Windalia Radiolarite.

Barrow No. 13

Type: Oil test.
License to Prospect: 113H.
Latitude and Longitude: 20° 49′ 50″ S., 115° 21′ 34″ E.
Elevation: Ground level 127 feet, derrick floor 138 feet.
Date commenced: 2nd November, 1965.
Date completed: 8th November, 1965.
Total depth: 2,356 feet.
Bottomed in: Lower Cretaceous.
Status: Oil well, completed over the intervals 2,138-2,143 feet, 2,149-2,155 feet, 2,157-2,160 feet, 2,165-2,169 feet, 2,175-2,187 feet, and 2,236-2,241 feet in the Windalia Radiolarite.

Barrow No. 14

Type: Oil test.
License to Prospect: 113H.
Latitude and Longitude: 20° 48′ 58″ S., 115° 22′ 30″ E.
Elevation: Ground level 168 feet, rotary table 179 feet.
Date commenced: 10th November, 1965.
Date completed: 17th November, 1965.
Total depth: 2,374 feet.
Bottomed in: Lower Cretaceous.
Status: Oil and gas well, completed over the intervals 2,122-2,132 feet, 2,137-2,156 feet, 2,159-2,165 feet, 2,168-2,178 feet, 2,197-2,201 feet and 2,217-2,224 feet in the Windalia Radiolarite.

Barrow No. 15

Type: Oil test.
License to Prospect: 113H.
Latitude and Longitude: 20° 51′ 08″ S., 115° 21′ 34″ E.
Elevation. Ground level 87 feet, rotary table 98 feet.
Date commenced: 18th November, 1965.
Date completed: 26th November, 1965.
Total depth: 2,251 feet.
Bottomed in: Lower Cretaceous.
Status: Oil well, completed over the intervals 2,014-2,024 feet, 2,045-2,053 feet, 2,097-2,103 feet, and 2,116-2,126 feet in the Windalia Radiolarite.

Barrow No. 16

Type: Oil test.
License to Prospect: 113H.
Latitude and Longitude: 20° 51′ 34″ S., 115° 20′ 39″ E.
Elevation: Ground level 66 feet, rotary table 77 feet.
Date commenced: 28th November, 1965.
Date completed: 3rd December, 1965.
Total depth: 2,399 feet.
Bottomed in: Lower Cretaceous.
Status: Oil well, completed over the intervals 2,165-2,177 feet, 2,182-2,197 feet, 2,222-2,228 feet, and 2,241-2,257 feet in the Windalia Radiolarite.

Barrow No. 17

Type: Oil test.
License to Prospect: 113H.
Latitude and Longitude: 20° 50′ 43″ S., 115° 20′ 39″ E.
Elevation: Ground level 94 feet, rotary table 105 feet.
Date commenced: 4th December, 1965.
Date completed: 11th December, 1965.
Total depth: 3,111 feet.
Bottomed in: Lower Cretaceous.
Status: Oil well, completed over the intervals 2,202-2,211 feet, 2,216-2,228 feet, 2,242-2,250 feet and 2,260-2,267 feet in the Windalia Radiolarite.

Barrow No. 18

Type: Oil test.
License to Prospect: 113H.
Latitude and Longitude: 20° 48′ 58″ S., 115° 26′ 30″ E.
Elevation: Ground level 61 feet, rotary table 72 feet.
Date commenced: 13th December, 1965.
Date completed: 22nd December, 1965.
Total depth: 2,623 feet.
Bottomed in: Lower Cretaceous.
Status: Dry, completed as observation well.

PERMIT TO EXPLORE 227H

Permit to Explore 227H is held by West Australian Petroleum Pty. Ltd. and has been farmed out to Continental Oil Company of Australia Ltd. and Australian Sun Oil Co. Ltd., with Continental as operator. The company began drilling its first test well, St. George Range No. 1, in this permit area during 1965.

St. George Range No. 1

Type: Oil test.
License to Prospect: 132H.
Latitude and Longitude: 18° 41′ 30″ S., 125° 08′ 11″ E.
Elevation: Ground level 566 feet, kelly bushing 584 feet.
Date commenced: 16th September, 1965.
Status: Drilling ahead at 9,053 feet on 31st December.

PERMIT TO EXPLORE 228H

Permit to Explore 228H has been farmed out by West Australian Petroleum Pty. Ltd. to French Petroleum (Australia) Pty. Ltd. and Australian Aquitaine Petroleum Pty. Ltd., French Petroleum being the operator. During 1965 two test wells, Arrowsmith No. 1 and Cadda No. 1, were drilled in this permit area.

Arrowsmith No. 1

Type: Oil test.
License to Prospect: 130H.
Latitude and Longitude: 29° 36′ 38″ S., 115° 06′ 53″ E.
Elevation: Ground level 168 feet, rotary table 184 feet.
Date commenced: 4th April, 1965.
Date completed: 19th June, 1965.
Total depth: 11,306 feet.
Bottomed in: Precambrian.
Status: Completed as potential gas well over the interval 9,244-9,256 feet. A drill-stem test of the interval 9,235-9,265 feet yielded 4 million cubic feet of gas per day.

Cadda No. 1

Type: Oil test.
License to Prospect: 151H.
Latitude and Longitude: 30° 20′ 15″ S., 115° 12′ 48″ E.
Elevation: Ground level 256 feet, kelly bushing 270 feet.
Date commenced: 27th July, 1965.
Date completed: 19th September, 1965.
Total depth: 9,169 feet.
Bottomed in: Precambrian.
Status: Dry and abandoned.

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	18·76 (land) 0·62 (marine)
Do. do. do.	28H	Carnarvon	0·68 (land) 0·46 (marine)
Do. do. do.	30H	Canning	14·02 (land)
Do. do. do.	217H	Carnarvon	0·92 (land 1·45 (marine)
Do. do. do.	225H	Perth	0·23 (marine)
Do. do. do.	233H	Carnarvon	0·24 (marine)
Continental Oil Co. of Australia Ltd.	226H	Carnarvon	16·28 (land) 0·23 (marine)
Do. do. do.	227H	Canning	12·0 (land)
French Petroleum Co. (Australia) Pty. Ltd.	228H	Perth	4·3 (land) 0·1 (marine)
B.O.C. of Australia Ltd.	213H	Canning	5·0 (marine)
Anacapa Corporation	127H	Bonaparte Gulf	3·5 (land) 3·0 (marine)
BP Petroleum Development Australia Pty. Ltd.	193H	Perth	1·0 (marine)
Do. do. do.	236H	Perth	0·25 (marine)
Arco Limited	221H	Bonaparte Gulf	0·75 (marine)
Hunt Oil Company	147H and 159H	Officer	6·3 (land)
Do. do.	134H	Officer	3·0 (land)

GRAVITY

During the year, gravity surveys were carried out in the Carnarvon, Canning, Officer, and Eucla Basins. This work was distributed as folows:

Company	Permit	Basin	Party Months
West Australian Petroleum Pty. Ltd.	27H	Perth	2·52
Do. do. do.	30H	Canning	3·72
Do. do. do.	217H	Carnarvon	2·0
Hunt Oil Company	134–136H and 159H	Officer	3·0
Australian Oil Corporation	209H and 210H	Eucla	3·0

MAGNETIC

A ground magnetic survey, totalling 0.66 party months, was carried out by Hunt Oil Company in Permits to Explore 135H and 148H (Officer Basin). Aeromagnetic surveys were carried out in the Carnarvon, Canning, Bonaparte Gulf, and Officer Basins. They were distributed as follows:

Company	Permit	Basin	Line Miles
West Australian Petroleum Pty. Ltd.	30H	Canning	4,000
Union Oil Development Corp.	205H–207H	Canning-Officer	20,131
Tasman Oil Pty. Ltd.....	235H	Carnarvon	5,100
Beach Petroleum N.L.	152H and 153H	Canning	4,205
Arco Limited	221H	Bonaparte Gulf	11,000

GEOLOGICAL OPERATIONS

Field geological studies were carried out in 1965 by oil exploration companies in the Carnarvon, Canning, Bonaparte Gulf, and Officer Basins. They were distributed as follows:

Company	Permit	Basin	Geologist Months
West Australian Petroleum Pty. Ltd.	28H	Perth	1
Do. do. do.	30H	Canning	2
Continental Oil Company of Australia Ltd.	226H	Carnarvon	2
Do. do. do.	227H	Canning	4
French Petroleum (Australia) Pty. Ltd.	228H	Perth	1·5
Anacapa Corporation	127H	Bonaparte Gulf	1·5
Beach Petroleum N.L.	151H	Canning	2
Do. do.	153H	Canning	2

During the year the Geological Survey continued its mapping programme in the southern part of the Perth Basin (one geologist for two months), and commenced a regional geological survey of the Eucla Basin (one geologist for 5 months). The Bureau of Mineral Resources completed the regional survey of the Bonaparte Gulf Basin, occupying two geologists for 4 months.

NOTES ON THE LEGEND OF THE GEOLOGICAL MAP OF WESTERN AUSTRALIA 1966

By R. C. Horwitz

INTRODUCTION

The Geological Map of Western Australia, 1966, was compiled from the work of the Geological Survey of Western Australia and other organizations. In some cases, this map presents the results of unpublished work. The map was compiled mainly by 1 inch to 4 miles, or 1:250,000 sheet areas (1° latitude and 1° 30′ longitude) which were later reduced and joined. A reliability diagram on the map shows where mapping at 1:250,000 or larger scale was available; elsewhere the geology was compiled from available data together with ground traverses and photo-interpretation. This applies in particular to the southwest coastal region. Most of the eastern goldfield areas have been reinterpreted from Bureau of Mineral Resources aeromagnetic maps.

Where possible, units have been classified according to age.

Intrusive rocks and zones of high-grade metamorphism are arranged separately in the legend.

PRECAMBRIAN UNDETERMINED

The unit 'Precambrian undetermined' is introduced to cover rocks when either their age, other than Precambrian, is unknown or when they have not been subdivided (e.g. basic dykes and sills).

Zones of high grade metamorphism, migmatites and gneiss

Crystalline rocks which are not wholly of igneous origin (migmatite and gneiss) or which are the result of regional metamorphism are grouped together.

The migmatite and gneiss are in a number of cases, the margins (or mantles) of granite. They are represented by mixed zones which contain granites rich in xenoliths, or banded rocks containing alternating layers of granitic rocks and rocks of sedimentary or volcanic origin.

Many of the metamorphic rocks are in the granulite facies. Charnockites are reported from the eastern part of the Eastern Division, from the eastern part of the Dundas Goldfield, and from the South-West Division. The metamorphism has affected rocks of both sedimentary and basic igneous origin. It is believed that this metamorphism has occurred, depending on regions, at least once in the Archaean and once in the Proterozoic.

Granite

The age of some Precambrian granite is imprecisely known. The mode of occurrence and the various facies resemble granites from both the Archaean and the Proterozoic. The features described for the Archaean granite can thus be applied, to a large extent, to other granites.

Basic dykes and sills

Basic dykes and sills have not been separated in age. Archaean and Proterozoic examples are known. In most cases, the dykes are represented diagrammatically; the trends are exact but in reality the dykes are more numerous and shorter.

Dykes are probably present between the Yilgarn Goldfield and the Perth region, although they have not been mapped east of longitude 117°.

Archaean sills, known as the Younger Greenstones, are generally not distinguished from the Archaean layered rocks.

Sedimentary and volcanic rocks

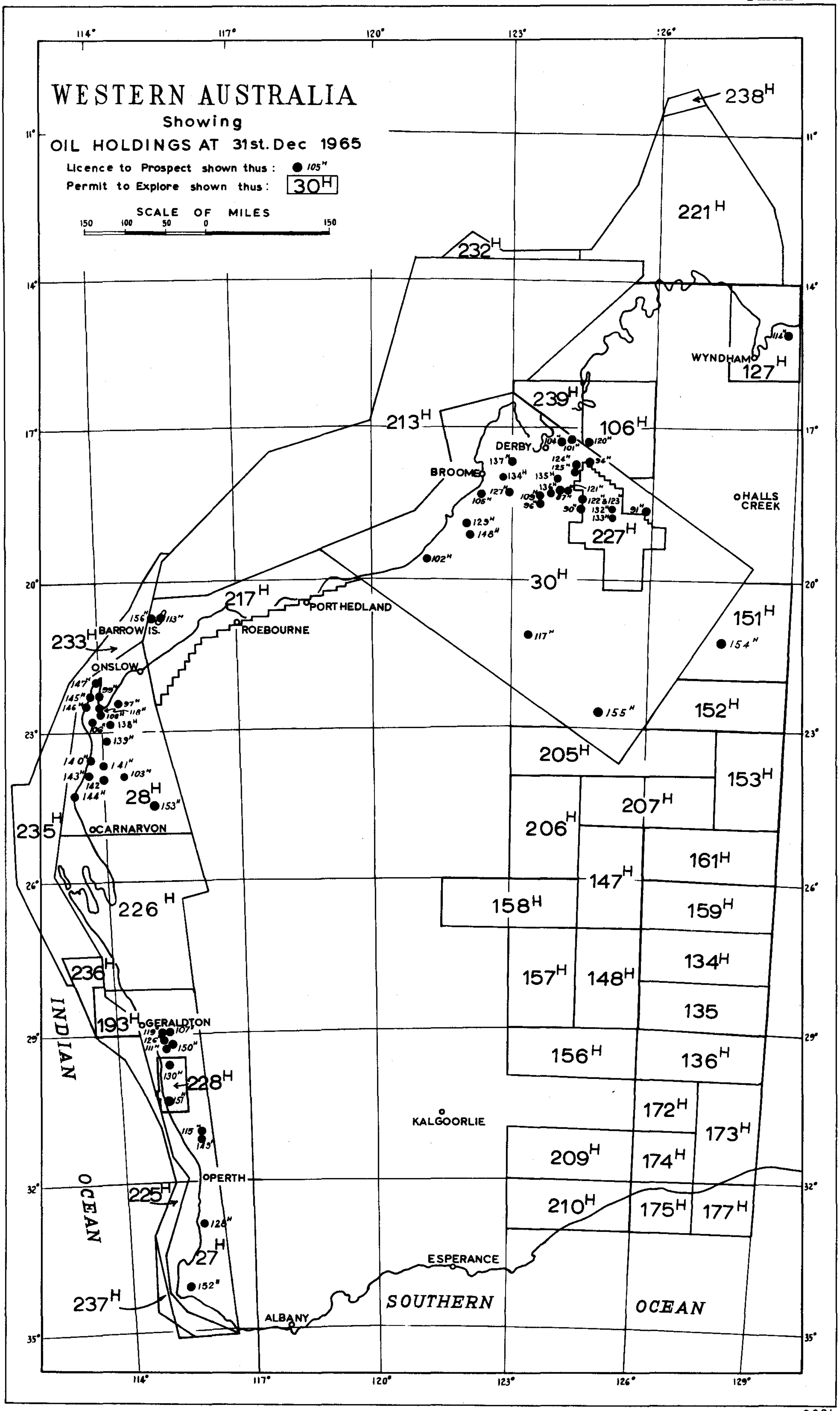
The sedimentary and volcanic rocks of the undetermined Precambrian differ in lithology, and probably in age, from one region to another. Along the eastern border of Western Australia, they have been subdivided into units which are probably separate in age. This relative chronology, devoid of reference to absolute age, is represented by a layering in the legend for sedimentary and volcanic rocks of undetermined Precambrian age. As stressed in the legend, separate areas with the same symbol are not necessarily of the same age.

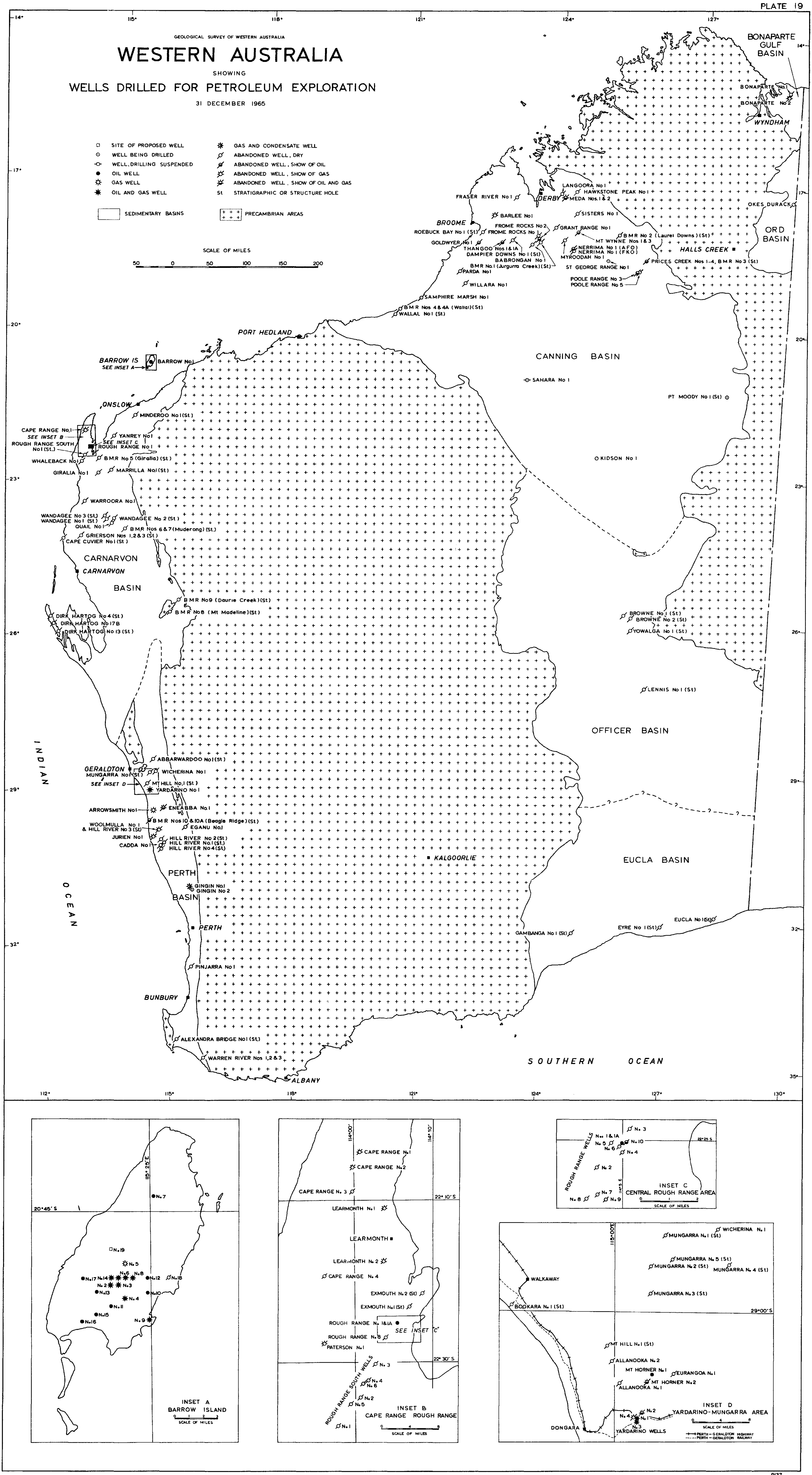
Near the eastern border, adjoining the Northern Territory and south of the Kimberley Division, the oldest of these rocks consists of volcanic and sedimentary deposits, and the youngest are sediments some of which are known to underlie the Upper Proterozoic. In the Paterson Range area of the Pilbara Goldfield, cleaved siltstones are believed to underlie the Middle Proterozoic. In the broad region between the Ashburton Goldfield and the Murchison Goldfield, and extending to the Geraldton area on the west coast, the rocks are an assemblage of granulite, gneiss and migmatite; the region probably includes Archaean and Lower Proterozoic rocks. In the extreme southwest, the Precambrian is mainly basic and acid granulite as well as migmatite. The rocks at Mt. Ragged, an area on the south coast, are cleaved quartzite and phyllite.

ARCHAEAN

Granite

Granites make up about half the area of Archaean in Western Australia. They are intrusive and are the youngest rocks in the Archaean. The granites sometimes have a wide gneissic margin of mixed sedimentary and granitic origin, whilst elsewhere, the contact with the host rock is abrupt. Contact metamorphism is irregular.


WESTERN AUSTRALIA
Showing
OIL HOLDINGS AT 31st. Dec 1965
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°
11° 14° 17° 20° 23° 26° 29° 32° 35°
129°
238H
221H
232H
WYNDHAM
127H
239H
106H
213H
DERBY
BROOME
OHALLS CREEK
227H
30H
217H
PORT HEDLAND
ROEBOURNE
BARROW IS.
233H
ONSLOW
151H
152H
205H
153H
207H
206H
28H
235H
CARNARVON
161H
147H
158H
159H
226H
134H
157H
148H
135
236H
193H
GERALDTON
156H
136H
228H
INDIAN
KALGOORLIE
172H
173H
209H
174H
PERTH
OCEAN
225H
210H
175H
177H
27H
ESPERANCE
237H
SOUTHERN
OCEAN
ALBANY


GEOLOGICAL SURVEY OF WESTERN AUSTRALIA
WESTERN AUSTRALIA
SHOWING
WELLS DRILLED FOR PETROLEUM EXPLORATION
31 DECEMBER 1965
SITE OF PROPOSED WELL
WELL BEING DRILLED
WELL, DRILLING SUSPENDED
OIL WELL
GAS WELL
OIL AND GAS WELL
GAS AND CONDENSATE WELL
ABANDONED WELL, DRY
ABANDONED WELL, SHOW OF OIL
ABANDONED WELL, SHOW OF GAS
ABANDONED WELL, SHOW OF OIL AND GAS
St STRATIGRAPHIC OR STRUCTURE HOLE
SEDIMENTARY BASINS
PRECAMBRIAN AREAS
SCALE OF MILES
50 0 50 100 150 200
BONAPARTE GULF BASIN
BONAPARTE No 1
BONAPARTE No 2
WYNDHAM
LANGOORA No 1
HAWKSTONE PEAK No 1
FRASER RIVER No 1
DERBY
MEDA Nos 1 & 2
OKES DURACK
BARLEE No 1
SISTERS No 1
BROOME
FROME ROCKS No 2
ROEBUCK BAY No 1 (St)
FROME ROCKS No 1
GRANT RANGE No 1
B M R No 2 (Laurel Downs) (St)
ORD BASIN
GOLDWYER No 1
MT WYNNE Nos 1 & 3
THANGOO Nos 1 & 1A
NERRIMA No 1 (AFO)
DAMPIER DOWNS No 1 (St)
NERRIMA No 1 (FKO)
HALLS CREEK
BABRONGAN No 1
MYROODAH No 1
B M R No 1 (Jurgurra Creek) (St)
PRICES CREEK Nos 1-4, B M R No 3 (St)
ST GEORGE RANGE No 1
PARDA No 1
POOLE RANGE No 3
WILLARA No 1
POOLE RANGE No 5
SAMPHIRE MARSH No 1
B M R Nos 4 & 4A (Wallal) (St)
WALLAL No 1 (St)
PORT HEDLAND
CANNING BASIN
BARROW IS
SEE INSET A
BARROW No 1
SAHARA No 1
PT MOODY No 1 (St)
ONSLOW
MINDEROO No 1 (St)
CAPE RANGE No 1
SEE INSET B
YANREY No 1
SEE INSET C
ROUGH RANGE SOUTH No 1 (St.)
ROUGH RANGE No 1
WHALEBACK No 1
B M R No 5 (Giralia) (St)
GIRALIA No 1
MARRILLA No 1 (St)
KIDSON No 1
WARROORA No 1
WANDAGEE No 3 (St)
WANDAGEE No 1 (St)
WANDAGEE No 2 (St)
QUAIL No 1
B M R Nos 6 & 7 (Muderong) (St)
GRIERSON Nos 1, 2 & 3 (St)
CAPE CUVIER No 1 (St)
CARNARVON
CARNARVON
BASIN
B M R No 9 (Daurie Creek) (St)
B M R No 8 (Mt Madeline) (St)
DIRK HARTOG No 4 (St)
DIRK HARTOG No 17B
DIRK HARTOG No 13 (St)
BROWNE No 1 (St)
BROWNE No 2 (St)
YOWALGA No 1 (St)
LENNIS No 1 (St)
OFFICER BASIN
INDIAN
OCEAN
ABBARWARDOO No 1 (St)
GERALDTON
MUNGARRA No 1 (St)
WICHERINA No 1
SEE INSET D
MT HILL No 1 (St)
YARDARINO No 1
ARROWSMITH No 1
ENEABBA No 1
B M R Nos 10 & 10A (Beagle Ridge) (St)
WOOLMULLA No 1 & HILL RIVER No 3 (St)
EGANU No 1
JURIEN No 1
HILL RIVER No 2 (St)
CADDA No 1
HILL RIVER No 1 (St)
HILL RIVER No 4 (St)
KALGOORLIE
EUCLA BASIN
PERTH BASIN
GINGIN No 1
GINGIN No 2
PERTH
EUCLA No 1 (St)
EYRE No 1 (St)
GAMBANGA No 1 (St)
PINJARRA No 1
BUNBURY
ALEXANDRA BRIDGE No 1 (St)
WARREN RIVER Nos 1, 2 & 3
SOUTHERN OCEAN
ALBANY
INSET A
BARROW ISLAND
SCALE OF MILES
20°45'S
115°25'E
INSET B
CAPE RANGE ROUGH RANGE
CAPE RANGE No 1
CAPE RANGE No 2
CAPE RANGE No 3
LEARMONTH No 1
LEARMONTH
LEARMONTH No 2
CAPE RANGE No 4
EXMOUTH No 2 (St)
EXMOUTH No 1 (St)
ROUGH RANGE No 1 & 1A
SEE INSET "C"
ROUGH RANGE No 8
PATERSON No 1
ROUGH RANGE SOUTH WELLS
22°10'S
22°30'S
114°00'
114°10'
INSET C
CENTRAL ROUGH RANGE AREA
ROUGH RANGE WELLS
22°25'S
INSET D
YARDARINO-MUNGARRA AREA
WICHERINA No 1
MUNGARRA No 1 (St)
MUNGARRA No 5 (St)
MUNGARRA No 2 (St)
MUNGARRA No 4 (St)
WALKAWAY
MUNGARRA No 3 (St)
BOOKARA No 1 (St)
29°00'S
115°00'E
MT HILL No 1 (St)
ALLANOOKA No 2
MT HORNER No 1
EURANGOA No 1
MT HORNER No 2
ALLANOOKA No 1
DONGARA
YARDARINO WELLS
PERTH - GERALDTON HIGHWAY
PERTH - GERALDTON RAILWAY

The granites are discordant, although in many cases the Archaean layered rocks appear to mantle them.

There are two predominant facies of granite. One facies is a medium to fine-grained equigranular granite; the other is usually coarser and porphyritic, with large potassic feldspar laths. The equigranular granite usually mantles the porphyritic one, but it has a wide range in thickness and is locally absent. The granites show contradictory age relationships, each crosscutting the other as well as showing gradational passage in places. They are thus both considered broadly contemporaneous and, in detail, of several ages. Many of the granites are folded.

Sedimentary rocks and sedimentary rocks containing basic igneous rocks

In the layered rocks of the Archaean, the areas with a large proportion of basic igneous rocks have been distinguished from areas of predominantly sedimentary rocks. These two units correspond largely to the Greenstone Phase and the Whitestone Phase of previous publications.

The basic igneous rocks are extrusive and intrusive and are mixed with sedimentary rocks and acid volcanic rocks in variable proportions. This complex suite is usually overlain by sediments without volcanic rocks. In some areas the basic igneous rocks thin out or are completely absent. Gold deposits are commonly found in areas with basic igneous rocks.

The sediments usually contain a high proportion of tuffaceous and reworked volcanic material. Banded iron formations are numerous.

LOWER PROTEROZOIC

The time boundaries of the Proterozoic are those adopted by the Geological Survey of Western Australia (1965).

The Lower Proterozoic extends from 2,440 m. y. to 1,640 m. y. In the North-West Division it contains at the base thick basalts which are overlain by a sequence of chemical sediments with banded iron formations. The latter are being developed as an important source of iron ore. In the western section of this region, the top of the Lower Proterozoic succession consists of clastic rocks (silty and sandy beds, now slates and phyllites). Acid volcanic rocks occur throughout the Lower Proterozoic sequence.

The Lower Proterozoic occurs also in the Kimberley region where acid and basic volcanic rocks are overlain by thick clastic deposits. The Lower Proterozoic succession of the Kimberley region is, on the whole, younger than that of the North-West. Both have been dated by isotopic methods.

MIDDLE PROTEROZOIC

The Middle Proterozoic extends from 1,640 m. y. to 900 m. y. Rocks assigned to this era are widely scattered throughout the State. They have been dated on the south coast region, in the North-East Coolgardie Goldfield, in the eastern part of the Eastern Division just south of 26° parallel, and in the Kimberley region.

Acid and basic volcanic rocks occur in the Lower Proterozoic of the eastern part of the Eastern Division. In the northern parts of the Mount Margaret and Murchison Goldfields, rhyolites and tuffs occur in the lower part of this unit.

UPPER PROTEROZOIC

Upper Proterozoic rocks occur in the Kimberley region and are believed to be present in the Eastern Division within the ranges that border the Northern Territory and South Australia. Rocks of this age grouping contain glacial deposits.

Granite

In the Kimberley region, Lower Proterozoic granite is overlain uncomformably by Lower Proterozoic deposits. Contemporaneous granite of the Ashburton and Gascoyne goldfields is intrusive into older deposits of this same age grouping.

Granite in the eastern part of the Eastern Division is younger than Middle Proterozoic rhyolite, but older than Upper Proterozoic deposits. The granite at Albany, in the southern part of the South-West Division, has been dated as Middle Proterozoic.

PALAEOZOIC

Cambrian

Basalt flows, overlain by marine sedimentary rock of Cambrian age, occur in the eastern part of the Kimberley region and extend eastwards into the Northern Territory. The volcanic rocks and the sediments are each about 3,000 feet thick.

Ordovician

Marine Ordovician sedimentary deposits occur sporadically in the region adjacent to the Northern Territory between Joseph Bonaparte Gulf and latitude 24°. Some 2,500 feet of Middle and Lower Ordovician shale and dolomite are known in the southern part of the Kimberley Division in the Canning Basin, and 500 feet of Lower Ordovician sediments occur in the Joseph Bonaparte Gulf region.

Silurian

The Silurian occurs only on the west coast, north of Geraldton. The 600-foot thickness of sandstone that crops out in the lower Murchison River area is tentatively considered to be Lower Silurian. More than 2,400 feet of Middle Silurian limestone and dolomite are known in depth around Shark Bay.

Devonian

The Devonian is known in the south and the east parts of the Kimberley region in the Canning and Bonaparte Gulf Basins; and in the Carnarvon Basin in the western part of the North-West Division. It contains richly fossiliferous limestone. In the Canning and Bonaparte Gulf Basins the Devonian includes well exposed reef complexes.

Carboniferous

Carboniferous sediments occur in the southern and eastern parts of the Kimberley region as well as in the western part of the North-West Division.

Permian

The Permian occurs sporadically in many parts of the State. The basal part of the section is believed to be of glacial origin, associated with the Sakmarian glaciation. The only commercial coal deposits in the State occur in the Permian at Collie, in the South-West Division.

MESOZOIC

Triassic

The Triassic occurs in the Canning Basin in the southern and western part of the Kimberley Division, as well as in the northern part of the Perth Basin, in the west coast region. Both sequences contain a Lower Triassic shale which is overlain by sandstone.

Jurassic

Marine and continental Jurassic sediments are present in the Perth and Carnarvon Basins adjacent to the west coast. They reach a thickness of 11,000 feet in the Cape Range Anticline on the northwest coast. Sediments of this system also occur throughout the Canning Basin. In the northern Canning Basin, leucite-bearing rocks occur in dykes, sills, and flows.

Cretaceous

Cretaceous sediments occur in every broad sedimentary basin of Western Australia. Recent mapping and palaeontological work has proved that there are more sediments of Cretaceous age than was previously known in the Officer Basin of Western Australia (between the Eastern Division and the Eucla Division). In the extreme southwest region, basalt is interstratified in the Cretaceous sediments.

CAINOZOIC

Tertiary

Marine Tertiary sediments are present in the Carnarvon and Perth Basins and in the Eucla Division. In the south coast region, approximately between longitude 118° and longitude 124°, the marine Tertiary is known now to be much more extensive than was previously believed.

Continental deposits and laterites, believed to be Tertiary, are widespread in Western Australia. Aluminous laterites are an important source of bauxite. In the northern part of the North-West Division, ferruginous pisolites infill fossil valleys and are considered to be of Tertiary age. These deposits are being developed as a source of iron ore.

Quaternary

Thin Quaternary deposits blanket much of Western Australia and are predominantly continental deposits. In general the Quaternary has not been shown on the map.

MINERAL DISTRIBUTION

Cainozoic

Mineral beach sands (ilmenite, rutile, zircon) occur in Pleistocene deposits in the South-West. Iron ore, bauxite and manganese deposits have been formed by the weathering of older Precambrian rocks during Tertiary and Pleistocene times in many parts of the State. Industrial minerals and rocks such as limestone, glass sands, clays and gypsum occur in deposits of Cainozoic age.

Mesozoic

The Mesozoic rocks in the sedimentary basins are highlly prospective for oil and gas, e.g., Cretaceous and Jurassic at Barrow Island. The Mesozoic sediments in the Perth Basin are important reservoirs of underground water.

Palaeozoic

Coal deposits occur in Permian rocks in the Perth Basin as at Collie. Natural gas has been detected in lower Palaeozoic sediments in the Bonaparte Gulf Basin. Lead and zinc occur in Devonian limestone in the Kimberley Division.

Precambrian

Proterozoic. Major iron ore deposits are associated with the extensive banded iron formations of the Proterozoic Hamersley Iron Province. Crocidolite (blue asbestos) also occurs in these iron formations. Manganese occurs in association with Proterozoic sediments in the North-West Division and bauxite has been developed on Proterozoic basalts in the North Kimberley region. Copper, lead and zinc mineralization is widespread in Proterozoic rocks in the North-West Division.

Archaean. Most of the principal gold deposits in Western Australia occur in Archaean metasediments and volcanic rocks, in the so called "greenstone" belts. Other minerals in the Archaean rocks include copper, nickel, chromite, lead, tin, tantalite, beryl, lithium minerals and chrysotile asbestos. Banded iron formations are common in the Archaean and are the host rocks of many important iron ore deposits. Industrial minerals in Archaean areas include magnesite, talc, vermiculite and graphite.

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PROVISIONAL SUBDIVISIONS OF THE PRECAMBRIAN IN WESTERN AUSTRALIA 1966

The accompanying chart (Plate 20) of provisional subdivisions of the Precambrian in Western Australia is a revision of that published in the Annual Report of the Geological Survey for 1964. Since then, additional data have confirmed many of the correlations and destroyed others.

The subdivisions adopted in the 1964 Annual Report are retained, and are those of the Canadian Geological Survey (Leech and others, 1963).

A considerable range of uncertainty is still indicated for some of the units. The changes from the 1964 Annual Report are made from a consideration of old data in the light of new information from field observations and the results of age determinations carried out at the Australian National University, Department of Geophysics, Canberra. Many of the new field observations were made during 1965 for the compilation of the 1966 edition of the Geological Map of Western Australia. The Bureau of Mineral Resources has favoured the application to Western Australia of a partly defined subdivision based on provincial time-rock units, including an Adelaidean System and a Carpentarian System. This has not been adopted here, because it is not proven that this new subdivision corresponds everywhere in Western Australia to a natural subdivision. Rather does it appear that the natural rock subdivision, selected to define the top of the Carpentarian System, varies in age from area to area (Horwitz, 1966). The proposal thus presents the same vicissitudes of correlation as any subdivision based on the convention of selecting a type area to establish universal time boundaries, as recently expounded by Trendall (unpublished), and the Canadian System has precedence.

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ANALOGIES IN THE PRECAMBRIAN

by R. C. Horwitz

INTRODUCTION

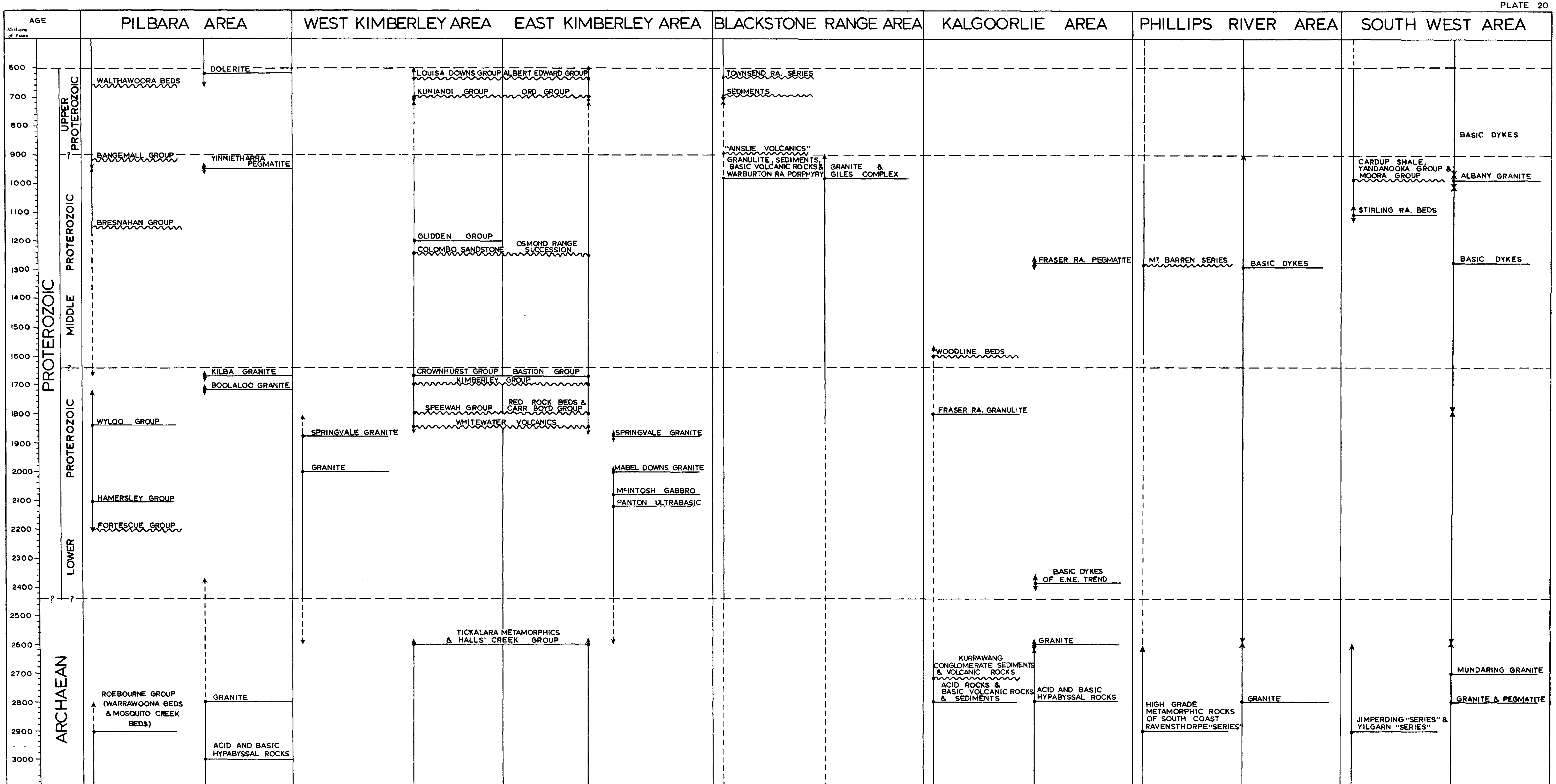
Analogies can be drawn between parts of the Precambrian sequences from various regions in Australia and these sequences can be conveniently compared to emphasize their similarities. However, analogy need not signify synchronism as can be shown for several analogous sequences from Australian Precambrian rocks on which age determinations have been made at the Australian National University. In spite of this, the similar sequences fit within time spans that appear to be close to some of the adopted subdivisions of the Precambrian (Geological Survey of Western Australia, 1965).

ARCHAEAN

Striking similarities have been noted in the sequence of events which have occurred in the Archaean of Western Australia, even though the analogous events are not contemporaneous, e.g. in the Pilbara and Kalgoorlie areas.

The following sequence is typical of the Archaean of Western Australia: the lower part of the sequence consists of basic igneous rocks followed by clastic sedimentation. Or, as it has been stated for the Yilgarn Goldfield "The Whitestones Series overlies the Greenstones Series" (Ellis, 1939, p. 67). As Ellis (p. 66) has noted, there are recurrences of basic volcanic rocks within sedimentary rocks.

Within the part of the sequence where clastic sediments occur, the basic volcanic rocks interfinger with the sedimentary rocks and have a wide range in thickness between different parts of each



AGE OF UNIT

- PROPOSED . . . . (solid line)
- PROPOSED (UNIT RESTS WITH A BASAL UNCONFORMITY) (wavy line)
- 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 FOR 1965

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province. Basic and acid hypabyssal rocks were intruded and folding has occurred during and after sedimentation. Chert and carbonate rocks occur throughout the sequence. The material in the clastic sediment is derived from all the rock types mentioned and local unconformities and coarse clastics suggest a local source area. Granite is amongst the last rocks to appear in this succession of events.

The following picture would account for this typical sequence: localised submarine vulcanicity which, through piling up of volcanic material as well as folding, develops into volcanic archipelagoes; these are eroded, supplying clastic sediment while igneous activity and folding proceeds.

OLDER PART OF THE PROTEROZOIC

The following sequence of events occurs frequently in Australia in the Lower and Middle Proterozoic: basic and acid hypabyssal rocks and lavas are intruded by granite which is then unconformably overlain by acid and basic lavas and intruded by their hypabyssal equivalents. Parts of this sequence are absent in places. However, as for the Archaean, the sequences are analogous but not contemporaneous. For example, rhyolites above the unconformity from the Kimberley region are about 1,800 m.y. old (Bofinger, in Roberts and others, 1965, p. 11), while in the Warburton Range (approx. 127° E. long., 26° S. lat.) rhyolites are about 1,000 m.y. old (Compston, pers. comm.). Different ages, between these two extremes, have been recorded for rhyolites or basalts that either closely precede or closely succeed granite intrusion, folding, and a period of erosion represented by an angular unconformity. Clean sandstones, arkoses, and carbonate rocks with stromatolites are frequently interlayered with the volcanic rocks. In places, the different sequences are overlain by Upper Proterozoic glacial deposits and fossiliferous Cambrian beds, and these features all add to the general resemblance of the various sections.

Without the guidance of isotopic dating, an observer attempting to establish the most probable correlations in various sections of this part of the Precambrian, would be struck by the similarities of different sequences and would be tempted to equate the Pepegoona Porphyry (Campana and others, 1961; Compston and others, in press) of the Northern Flinders Ranges of South Australia with the Warburton Range Porphyry (Sofoulis, 1962; Horwitz and Sofoulis, 1963); and to equate the Carson Volcanics (Dow and others, 1964) of the Kimberley region with the Wooltana Volcanics (Mawson, 1926; Thomson and Coats, 1964; Compston and others, in press) of the Northern Flinders Ranges. One would thus be led to equate rocks from the "Carpentarian System" with rocks from the "Adelaidean System".

UPPER PROTEROZOIC GLACIAL BEDS

The glacial deposits of the Upper Proterozoic in Australia were first recognized by Howchin (1901) in South Australia. Mawson (1912) studied the glacial deposits in New South Wales and established their marine origin. Campana and Wilson (1955) emphasized the persistence of the glacial units throughout South Australia. Recently, Dow (1965) reviewed the evidence for the origin of these glacial beds in the Kimberley region of Western Australia.

Figure 11 outlines the distribution of these glacial deposits, interpolated through areas covered with younger rocks. The glacials stretch from the Kimberley region, in the northwest, through central Australia, to the Mt. Lofty Ranges in South Australia in the southeast and to the east of the Barrier Ranges in New South Wales.

Thin glacial beds have recently been recognized in the Warburton Ranges, between the "Ainslie Volcanics" (Sofoulis, 1962) and the sandstones of the Townsend Range Series (Talbot and Clarke, 1917). In South Australia, the glacial beds thin out towards the west (Sprigg, 1952; Shepherd and Thatcher, 1959) and the Gawler Ranges have been recognized as a source area for glacial beds in the Central Flinders Ranges (Horwitz, 1962). This pattern of distribution suggests that the southwestern boundary of the glacial beds is not a younger structural feature but that it was probably a shore-line at the time of deposition. It is interesting to note that the western boundary of the glacial beds is also close to being the southwestern limit of known Cambrian deposits in Australia.

A convenient division may be made at the base of the glacials which are transgressive wherever studied. The base of the glacials is older than 700 m.y. (Compston, pers. comm.).

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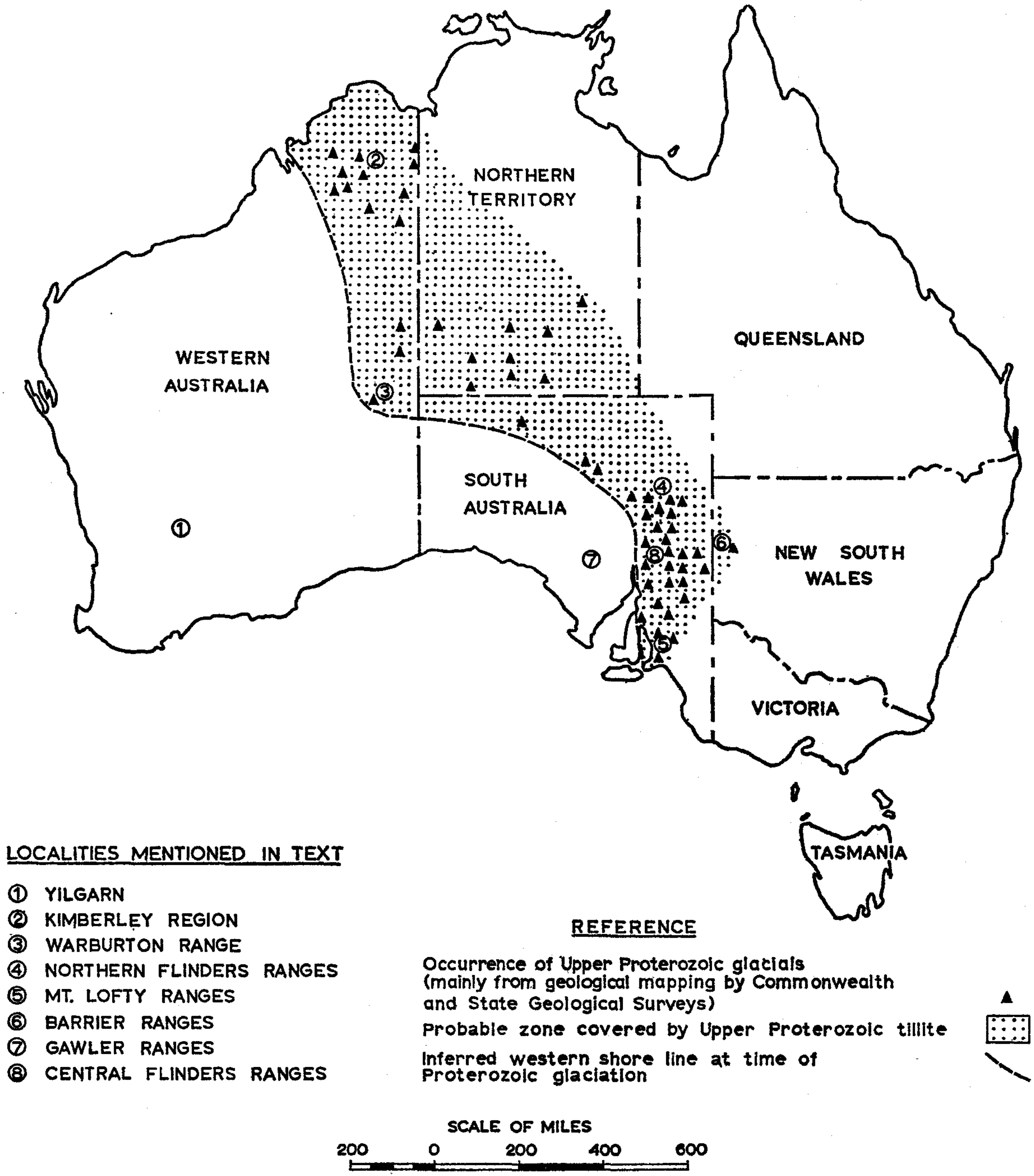

FIGURE 11
DISTRIBUTION IN AUSTRALIA OF UPPER PROTEROZOIC GLACIAL BEDS

REVISED STRATIGRAPHY, PALAEOCURRENT SYSTEM AND PALAEOGEOGRAPHY OF THE PROTEROZOIC BANGEMALL GROUP

by J. L. Daniels

ABSTRACT

The stratigraphy of the Proterozoic Bangemall Group is revised, dividing the Top Camp Dolomite into seven new formations: Coodardoo Sandstone, Curran Formation, Ullawarra Formation, Devil Creek Formation, Discovery Chert, Kiangi Creek Formation, and Irregully Formation.

The Bangemall Group was deposited in a basin which derived coarse sandy material from the northwest, north, or northeast, and finer sediments from the south and southeast. The basin was elongated in a northwest direction, with later northwest folding.

SUMMARY OF PALAEOGEOGRAPHY

The Bangemall Group extends westward from the Parry Range, forming most of the high country south of the Ashburton River and occupying a large part of the country between Mundiwindi and Mt. Sydney. This part of the Bangemall outcrop has an arcuate form, centred around Wittenoom Gorge.

During the early stages in the development of the basin the current pattern was irregular; probably caused by local irregularities of the basin floor and contemporaneous earth movement associated with the initial marine transgression. After the deposition of the Discovery Chert, conditions settled down to a simple pattern. Each major change in lithology, represented by formational boundaries, was presumably caused by changes in physical conditions and accompanied by a readjustment of the current system to these new conditions.

There is evidence of a land mass to the north and northeast early in Irregully Formation times and onwards, but apparently not before Coodardoo Sandstone times did this mass supply much sediment to the developing basin. After Coodardoo Sandstone times, supply from this land mass was intermittent being in the nature of turbidity currents flowing into a basin largely accumulating shale.

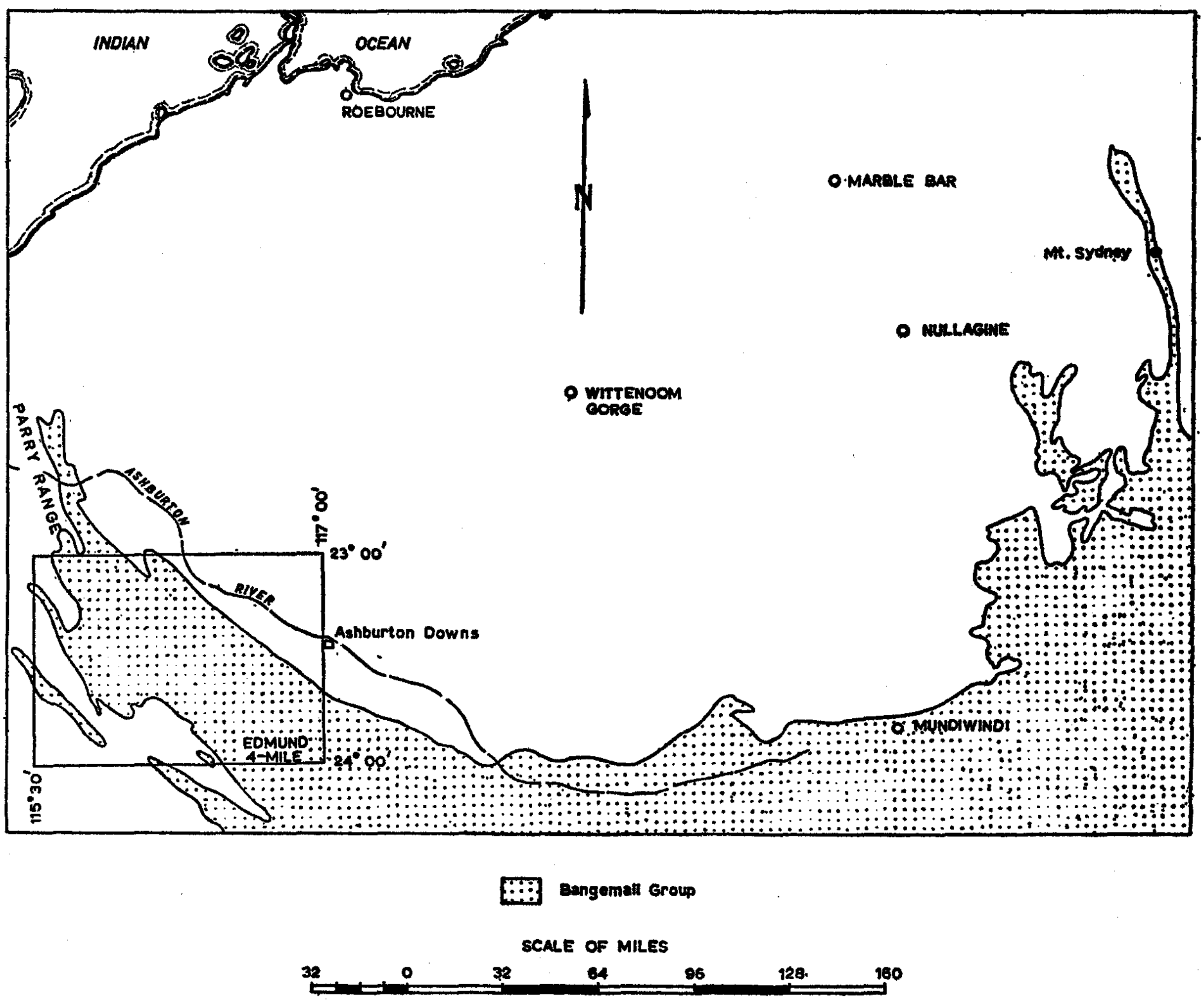

FIGURE 12 MAP OF PART OF NORTH-WEST DIVISION SHOWING AREA OF STUDY AND DISTRIBUTION OF BANGEMALL GROUP ROCKS

In general, the coarse sandy material of the group was mainly derived from the northwest, north or northeast, while the finer grained siltstone and mudstone were deposited from currents from the southeast and south.

It is thought that the northern edge of the basin may have been near the present line of the unconformity, but there is evidence to indicate that this was an oscillating zone. No position for the southern edge of the basin can be suggested. However, isopachs for the Discovery Chert and the Devil Creek Formation both seem to indicate a deepening of the basin to the south and southwest. Therefore the overall shape of the basin is uncertain except that in the Edmund 4-mile Sheet area it had a northwest to southeast elongation.

In the northwest central part of the area complications in the isopach maps for the Discovery Chert and Devil Creek Formation suggest the action of posthumous folding along axes trending approximately northeast. This direction corresponds with an anomalous trend in the Ashburton Formation, underlying the Bangemall Group, just north of the junction of Irregully Creek and the line of the unconformity. The same trend reappears as a second folding (i.e. post-Edmundian folding, Halligan and Daniels, 1964) locally affecting Bangemall Group rocks in the Devil Creek Area.

STRATIGRAPHY

Earlier mapping of part of the Bangemall Group in Turee Creek and Newman Sheet areas provided a simplified, three-fold division (Halligan and Daniels, 1964):

Top

Kurabuka Formation.

Fords Creek Shale.

Top Camp Dolomite.

More recent mapping in the Edmund Sheet area allows a more detailed subdivision of the Top Camp Dolomite. This name is now discarded. The revised stratigraphy is given in Table 1.

Table I

STRATIGRAPHY OF THE BANGEMALL GROUP—EDMUND SHEET AREA

Formation	Lithology	Thickness in feet
Top—		
Kurabuka Formation	Sandstone, shale, dolomitic shale	
Fords Creek Shale	Shale, silty shale, chert, sandstone	5,000–6,000 (approx.)
Coodardoo Sandstone	Sandstone with rare siltstone and shale	550–1,200 (minimum)
Curran Formation	Shale, siltstone, chert	250 (approx.)
Ullawarra Formation	Siltstone, shale, dolomite, rare sandstone	?
Devil Creek Formation	Dolomite, dolomitic mudstone, shale, rare sandstone and chert	200–1,200
Discovery Chert	Chert	200–1,000 (approx.)
Kiangi Creek Formation	Sandstone, shale, chert, rare dolomite	
Irregully Formation	Dolomite, chert breccia, sandstone, siltstone, shale	

DESCRIPTIONS OF FORMATIONS AND PALAEOGEOGRAPHY

Irregully and Kiangi Creek Formations

These formations are described together as they are, in part, lateral facies equivalent of each other. However, it is possible that most of the Irregully Formation is older than the Kiangi Creek Formation.

The Irregully Formation is a thick sequence consisting dominantly of a variety of dolomites and associated chert breccias with interbedded sandstone, shale, siltstone, and rare conglomerate. Subdivision of this unit is possible locally, but it is frequently difficult to trace individual members far, because of wedging of some of the units and local contemporaneous erosion. The chert breccias are the result of contemporaneous erosion caused by local earth movements. They occur as large sheets of very variable thickness overlying, in a number of places, an irregular land surface. The breccias are similar to those described from the Parry Range region to the northwest (Daniels, 1965). The majority of the fragments making up the breccias are composed of silicified algal dolomite and, by comparison of lithology, are regarded as having originated from a pre-existing Irregully Formation dolomite, many examples of which are preserved in the country between the Henry and Irregully Rivers.

In the Henry River region the Irregully Formation may be subdivided as follows:

Top

Well-banded sandy dolomite.
Sandstone.
Well-banded dolomite with algal bands and local breccia bodies.
Massive cream to white dolomite.
Thin, variable sandstone.
Unconformity.

Current bedding orientation measurements in the basal sandstone, about 6 miles west of the confluence of the Henry River and Kiangi Creek, indicate that currents moved in westerly and southwesterly directions. Further south and west, near the south end of the Henry—Telfer granite, the same sandstone horizon has been deposited from currents moving to the northwest. Near the northwestern corner of the Edmund Sheet area the basal sandstone has been considerably thickened by the addition of sand from the northwest. The northwesterly trending currents are still present, but of minor significance.

The swing of the currents, indicated by current bedding in the basal sandstone, around the southern end of the Henry—Telfer granite suggests that this region may have been an island, a peninsula, or a mound which influenced currents in the early stages in the deposition of the Bangemall Group.

Dolomites were deposited over the basal sandstone. Some horizons carry abundant algae (Plate 21A), probably indicating quiet, shallow water conditions. However, sedimentary chert breccias are common, indicating spasmodic local erosion and deposition. These features suggest an irregular early development of the basin.

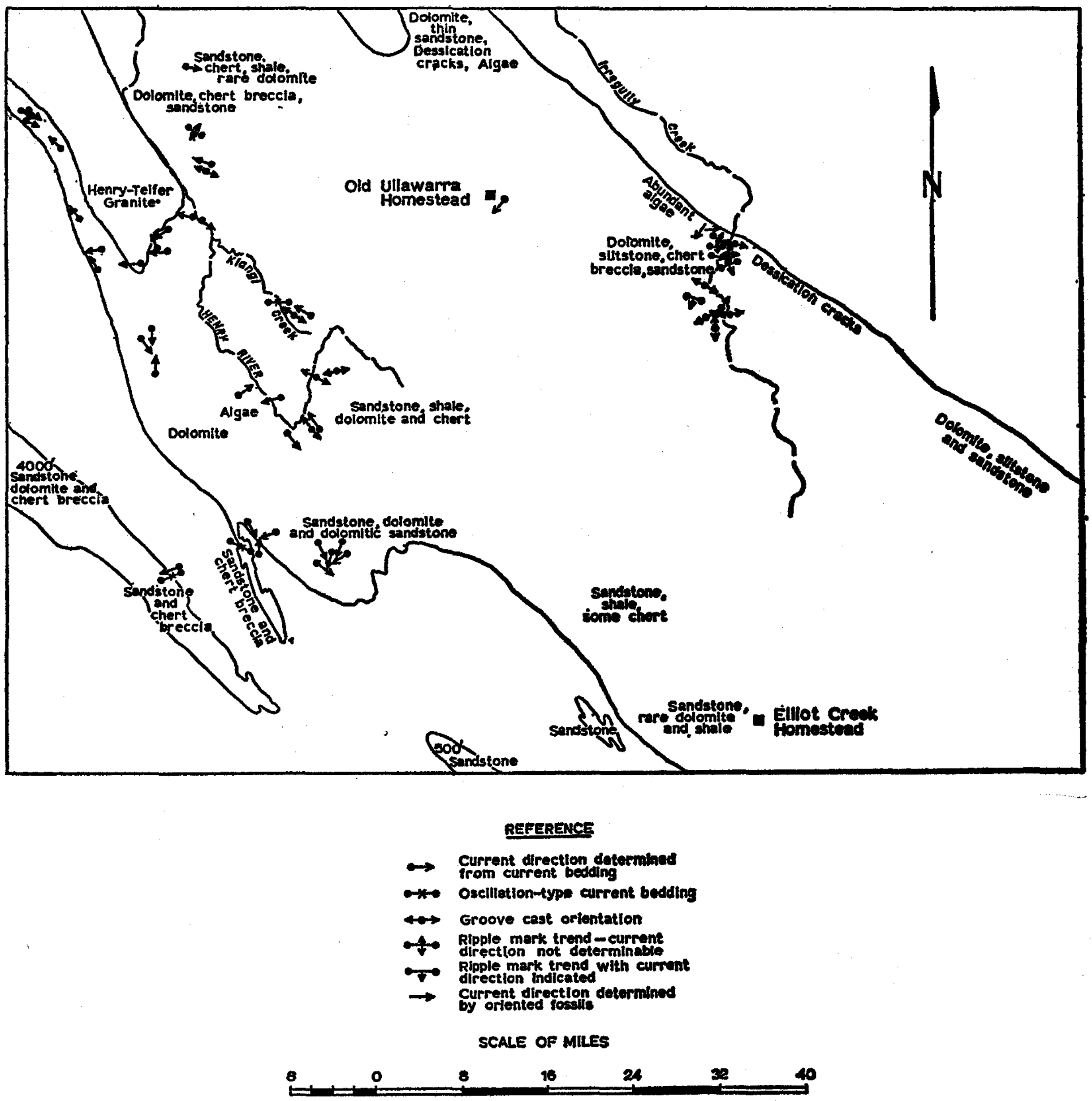

FIGURE 13 PALAEOCURRENT DIRECTIONS AND MAIN LITHOLOGY FOR IRREGULLY AND KIANGI CREEK FORMATIONS

Current bedding directions for the next stratigraphically higher unit, a wedge of sandstone, indicate a provenance to the west. A similar provenance is indicated for a current-bedded, sandy, dolomite horizon in the overlying unit, but insufficient measurements are available. It appears however, that during the formation of these upper dolomites there was a small but constant influx of rounded sand grains.

In the lower part of the Irregully Formation, in Irregully Creek, very variable current directions are indicated by measurements of ripple marks, oriented fossils, and current bedding. No consistent pattern was forthcoming. Abundant algal structures are present and these, together with the presence of dessication cracks in interbedded muddy dolomite, suggests an intertidal environment. Thin shale, a quartz pebble conglomerate and thin sandstones occur interbedded with the dolomite. In the sandstones small fragments of red jaspilite suggests derivation from the Hamersley Group lying to the north.

Twenty miles north-northwest of old Ullawarra Homestead, sands interbedded with algal dolomites and "edgewise" conglomerate show dessication cracks and ripple marks with superimposed possible swash structures. These features indicate periods of subaerial conditions. Here, also, rounded jaspilite pebbles in the sandstones suggest an influx of material from the north.

The basal unit in the Elliot Creek region, the Kiangi Creek Formation, is composed of sandstone with very rare lenses of dolomite and some shale. The formation apparently thickens towards Mt. Augustus suggesting the presence of a strand line to the south or southeast.

West-northwest from Elliot Creek, the Kiangi Creek Formation interfingers with the Irregully Formation. In this zone sandy dolomites and dolomitic sandstones are common and show current bedding. Measurements of the latter show that the currents flowed from the north though the overall spread of directions is wide, being from west-northwest, through north to northeast.

Above this zone of interdigitation more sandstones with some shale and chert horizons are present. These apparently blanketed the whole region. Few current measurements are available for the upper part of this dominantly sandstone sequence. In the Kiangi Creek itself, measurements of groove casts, flute casts, and current bedding indicate a supply of the sandstone from the southeast. Some 2 miles south of Old Ullawarra Homestead, current bedding indicates that supply was from the northeast for the upper part of the Kiangi Creek Formation in that region.

For the whole of the Irregully and Kiangi Creek Formations current directions were very variable both laterally and throughout the duration of the formations (Figure 13). No overall pattern can be determined yet and it would appear that this variability is the result of the initial, uneven development of the Bangemall basin.

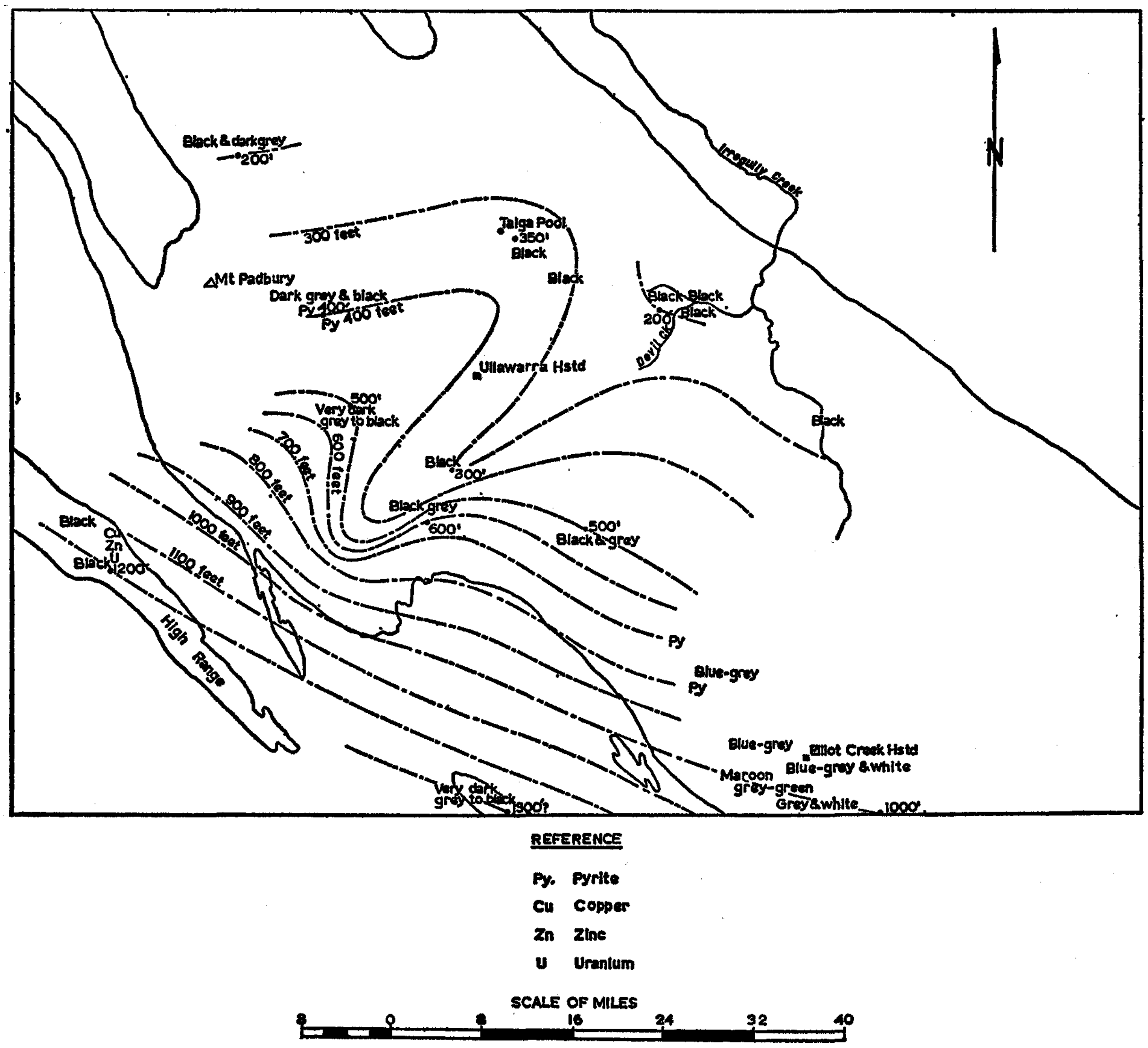

FIGURE 14 ISOPACHS FOR DISCOVERY CHERT

Discovery Chert

Overlying the Kiangi Creek Formation is a distinctive, thin bedded, chert formation varying in thickness from approximately 200 feet in the north near Talga Pool and Devil Creek to about 1,000 to 1,200 feet in the south and southwest (Figure 14).

The colour of the chert shows a regional zonal scheme. In the Elliot Creek region the fresh chert is light-grey and white, while a few miles to the northwest the depth of colour increases and blue-grey, greenish grey and maroon cherts are present. Outwards from the Elliot Creek region the depth of colour increases rapidly. Along its northeastern, northern, western and southwestern outcrop the chert is generally black.

Pyrite disseminations occur in the chert in the central region between Mt. Padbury and Elliot Creek Homestead. In a very general sense the regional distribution of the visible pyrite coincides with that of the medium-coloured chert, being, apparently, absent in the very light or black varieties. Traces of copper, zinc, and uranium are found in black chert in the southwest in High Range.

Isopachs for the formation show a general northwesterly strike with a thickening to the southwest, suggesting that the Bangemall basin, in the times of the Discovery Chert was deepest towards the southwest.

Between Mt. Padbury and Ullawarra the isopach map shows zones of thickening and thinning of the chert. This may have been caused by the presence of a ridge and parallel trough trending approximately 055°.

It is suggested that chemical precipitation of the chert took place on a subaqueous slope dipping to the southwest where reducing conditions prevailed. No evidence for the proximity of the southern or southwestern edge of the basin is forthcoming from the study of the Edmund Sheet area. No detrital material is known to have been added to the basin during the chert formation.

Devil Creek Formation

Immediately overlying the Discovery Chert is a thin-bedded sequence composed dominantly of dolomite. It ranges in thickness from 200 to 1,200 feet and generally thickens from the northeast to southwest (Figure 15).

In the Elliot Creek region the formation consists of thin-bedded dolomite with some thin sandstone and chert bands. Locally, variegated maroon and cream mudstone and dolomitic shale are present. Traces of manganese as a surface bloom and in dolomite breccia are noted.

In Irregully Creek, 20 miles north-northwest of Coodardoo Gap, the Devil Creek Formation consists of bedded dolomite, some bands of which carry abundant cryptozoon-type stromatolites. The latter range in length from 18 inches to 30 inches and in diameter from 2 inches to 5 inches.

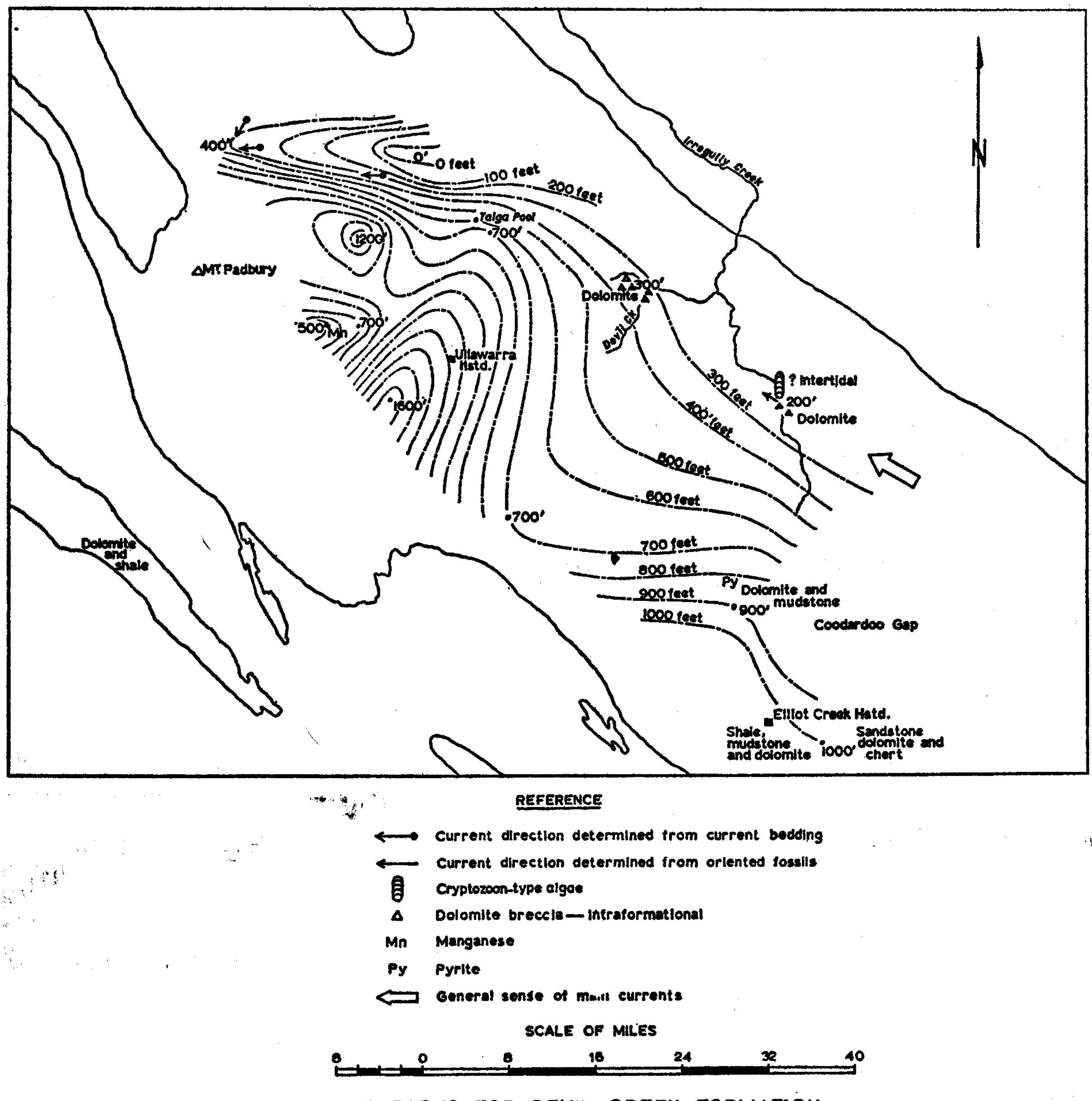

FIGURE 15 ISOPACHS FOR DEVIL CREEK FORMATION

All lie parallel to the bedding plane and show a preferred orientation of 124°. Their tops all point in this direction and it is considered that they were arranged in this manner by a current from the south-southeast. Intraformational dolomite breccia occurs a few hundred yards to the south in approximately the same horizon. A much more extensive deposit of very coarse brecciated dolomite occurs in Devil Creek itself. Here the breccia lies with a slight angular discordance over thin-bedded, unbrecciated dolomite, some parts of which have been recemented by fine and somewhat wavy, banded dolomite.

West of the above localities, the Devil Creek Formation consists of two distinct members. At the base is a distinctive very finely banded, blue-grey, brown-weathering dolomitic mudstone. Current bedding has been noted on a very fine scale, but is rare. Above the dolomitic mudstone occurs thin-bedded yellow weathering dolomite with frequent maroon and brown stains. Pyrite and manganese nodules are not infrequent locally.

The isopach map of the formation is not unlike that for the underlying Discovery Chert in showing a general thickening to the southwest and irregularities in the region between Mt. Padbury and Ullawarra.

Some 8 miles northwest of Talga Pool the formation is apparently absent, while the presence of abundant conophyton-type algae between Devil Creek and Irregully Creek suggest intertidal conditions and proximity to the shore. The coarse intraformational breccia southwest of the algal dolomite localities may be interpreted as a fore reef facies.

The indications are that land existed to the north and northeast during Devil Creek times but did not apparently supply detrital sediments to the basin. The presence of thin bands of sandstone in the Elliot Creek region may indicate proximity to a shore in that region.

The few current directions available are consistent, and together with the other details suggest that they are the result of a long shore current moving in a northwesterly to westerly direction.

Ullawarra Formation

The Ullawarra Formation consists of a very variable sequence of thin-bedded black and maroon shale, siltstone, and mudstone with smaller amounts of grey and maroon dolomite, greywacke, and chert. Manganese staining is common especially around Elliot Creek. Pyrite is present in some of the shale in the Ullawarra region.

A large number of dolerite sills intrude the sequence. They appear to keep within the formational boundaries, but individual sills within the formation are frequently transgressive. Sills are apparently most abundant in the northwestern part of the present outcrop.

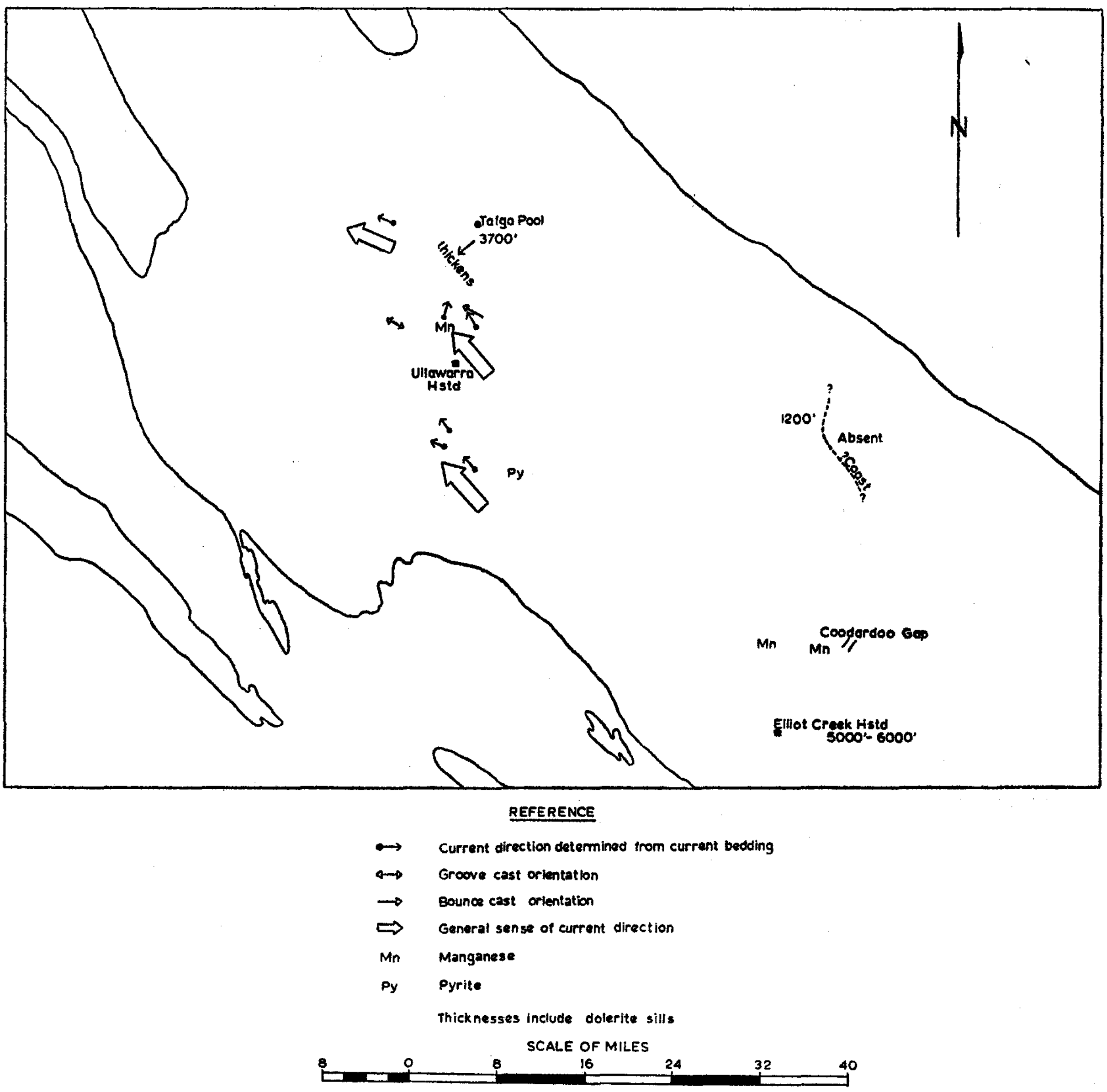

FIGURE 16 PALAEOCURRENT DIRECTIONS FOR ULLAWARRA FORMATION

On account of the presence of the dolerite sills and the strong folding which has affected the area, accurate thickness measurements are difficult. Near Coodardoo Gap the total thickness of sediments and sills is between 5,000 feet and 6,000 feet. Near Talga Pool the thickness is approximately 1,800 feet, while 18 miles north of Coodardoo Gap it is about 1,200 feet. Immediately to the east of the latter locality the Ullawarra Formation thins out rapidly and is possibly represented in this area, and for a considerable distance to the southeast, by a bedded chert breccia varying in thickness from 5 to 10 feet.

Palaeocurrent directions have been determined by measurements of current bedding attitudes in mudstone and more rarely by groove casts, bounce casts and brush casts on the soles of thin greywacke beds in shale. Measurements of both the depositional and erosional features give generally similar results. In one case where the two were measured on a single greywacke bed, groove and bounce casts indicated an erosional current from a direction of 108°, while current bedding at the top of the bed indicated a depositional current from a direction of 140°.

The overall results show a simple picture indicating that the main transport direction was from the southeast (Figure 16). Again, land probably existed to the northeast but no evidence for supply of material from that area is forthcoming. The pyritic nature of some of the shale in the Ullawarra region suggests that deep water conditions prevailed in that area.

Curran Formation

The Curran Formation is approximately 250 feet thick, but apparently thickens to about 500 feet in the southeast. It is a distinctive light-weathering formation consisting of thin-bedded shale, mudstone, siltstone, and chert with rare thin dolomite and occasional thin greywacke near the top. Directional sedimentary structures are rare. An example of current bedding in a siltstone in Irregully Creek indicated a current from the southeast.

Coodardoo Sandstone

The Coodardoo Sandstone consists essentially of dark greywacke with a range in thickness of 500 feet to approximately 1,200 feet and thins to the southeast. Shaly siltstone horizons occur near the top, but are of minor importance.

The Coodardoo Sandstone overlies the Curran Formation and between the two is a "transition zone", about 60 feet thick, consisting of alternating beds of dark grey-green to black shale and thin greywacke. The latter are dark grey, frequently of glassy appearance and range in thickness from 2 inches to 18 inches (Plate 21B). The proportion of greywacke to shale increases stratigraphically upward. Above the "transition zone" greywacke forms most of the deposit. The soles of nearly all the greywacke in the "transition zone" show abundant groove casts and more rarely bounce and flute casts (Plate 22). Graded bedding and repeated fine banding is present in the lower three-quarters of most of the beds. The former is never particularly

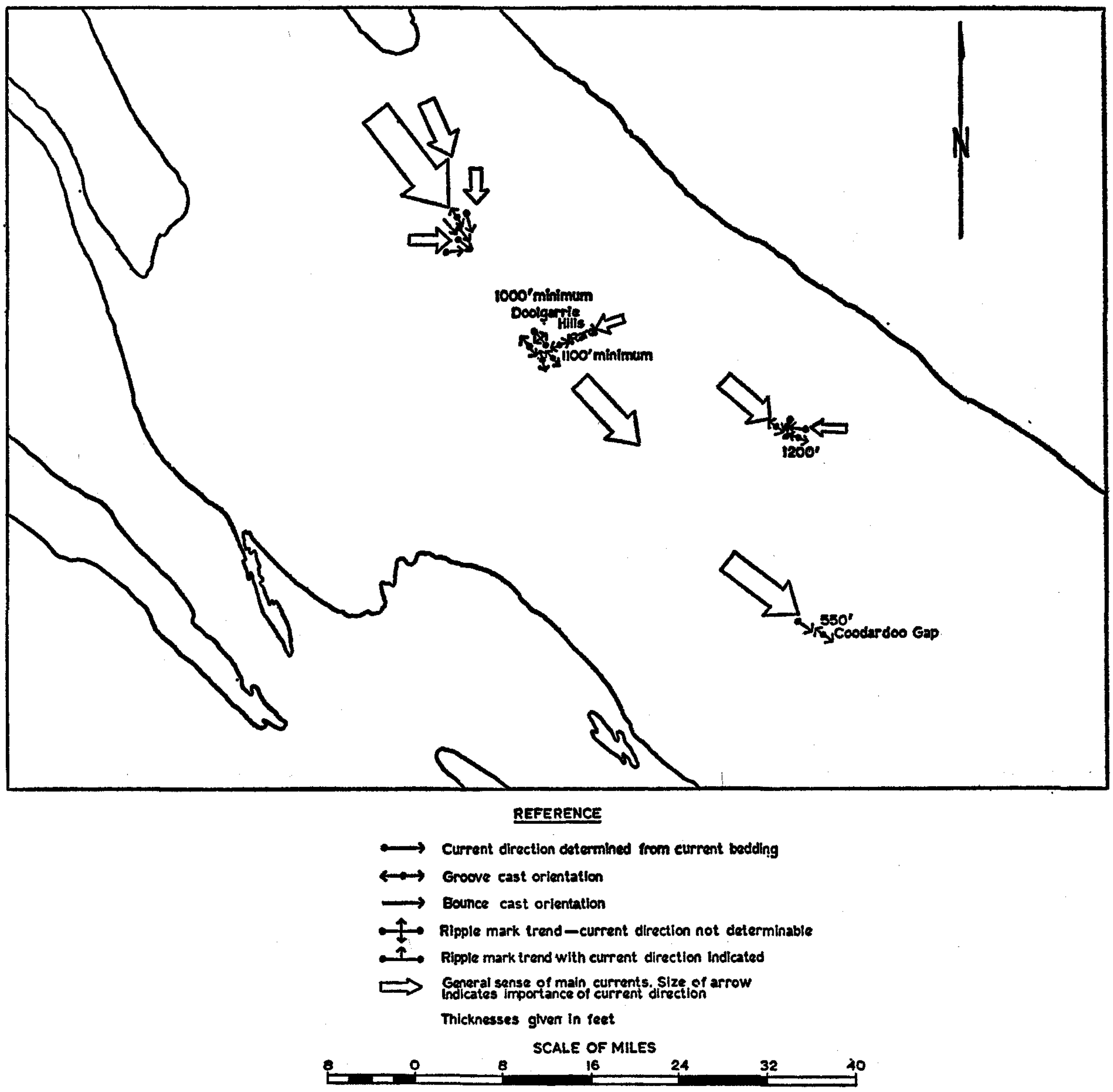

FIGURE 17 PALAEOCURRENT DIRECTIONS FOR COODARDOO FORMATION

well developed. The upper part of each band consists of fine-grained silty sediment often with current bedding. Between these two zones there is frequently a concentration of fine grained pyrite, which also occurs as rare scattered crystals throughout the lower unit.

In thin-section the lower unit is seen to consist of a mixture of rounded and angular grains of quartz, feldspar, and rock fragments with an abundant fine-grained matrix in which quartz, sericite, chlorite, biotite, carbonate, and iron oxides have been identified. Zircon, tourmaline, and sphene are present as rare subhedral to rounded grains. Rock fragments mostly consist of chert with smaller amounts of quartzite, granophyre, and (?) an acid volcanic rock.

The overall nature of these rocks suggests that they are turbidity current deposits and the nature of the fragments indicate a source area to the west, northwest, and north.

A detailed study has been made of the palaeocurrent indicators in the greywacke and a comparison made between the directions indicated by the erosional and depositional features. The erosional features used were groove casts, flute casts and bounce casts. Current bedding and more rarely ripple marks were used to determine the current direction during the latter part of the depositional phase.

Near the base of the "transitional zone" the erosional features indicate a current direction in an east-west sense. Groove casts only were measured and the direction could not be determined from these features. Current bedding indicates a source direction lying to the northwest (320°). Some 12 feet higher up the sequence, bounce casts indicate a northwest origin for the erosional currents, while near the top of the measured section a source from the north is indicated. Between these two limits, intermediate erosional current directions were measured and shown to change progressively from west-east to north-south. Throughout the whole, except for one example, the depositional current retained a constant trend indicating a source from the northwest.

The results seem to indicate that the source of material lies approximately to the west, northwest and north, but that the configuration of the basin changes gradually and consistently.

It seems highly unlikely that a succession of turbidity currents would show such a regular change in direction across a stable sea floor. The simplest explanation to account for this feature is that at the beginning of the period represented by the "transition zone", the basin had an easterly-dipping bottom slope. Gradually the land to the north was elevated and this would have the resultant effect of rotating the maximum sea floor dip from east to south.

A transport direction from the northwest is indicated for a large part of the present outcrop of the Coodardoo Sandstone. However, near the Doolgarrie Hills, and approximately 18 miles north-northwest of Coodardoo Gap, minor additional material from the northeast has been added to the deposit (Figure 17).

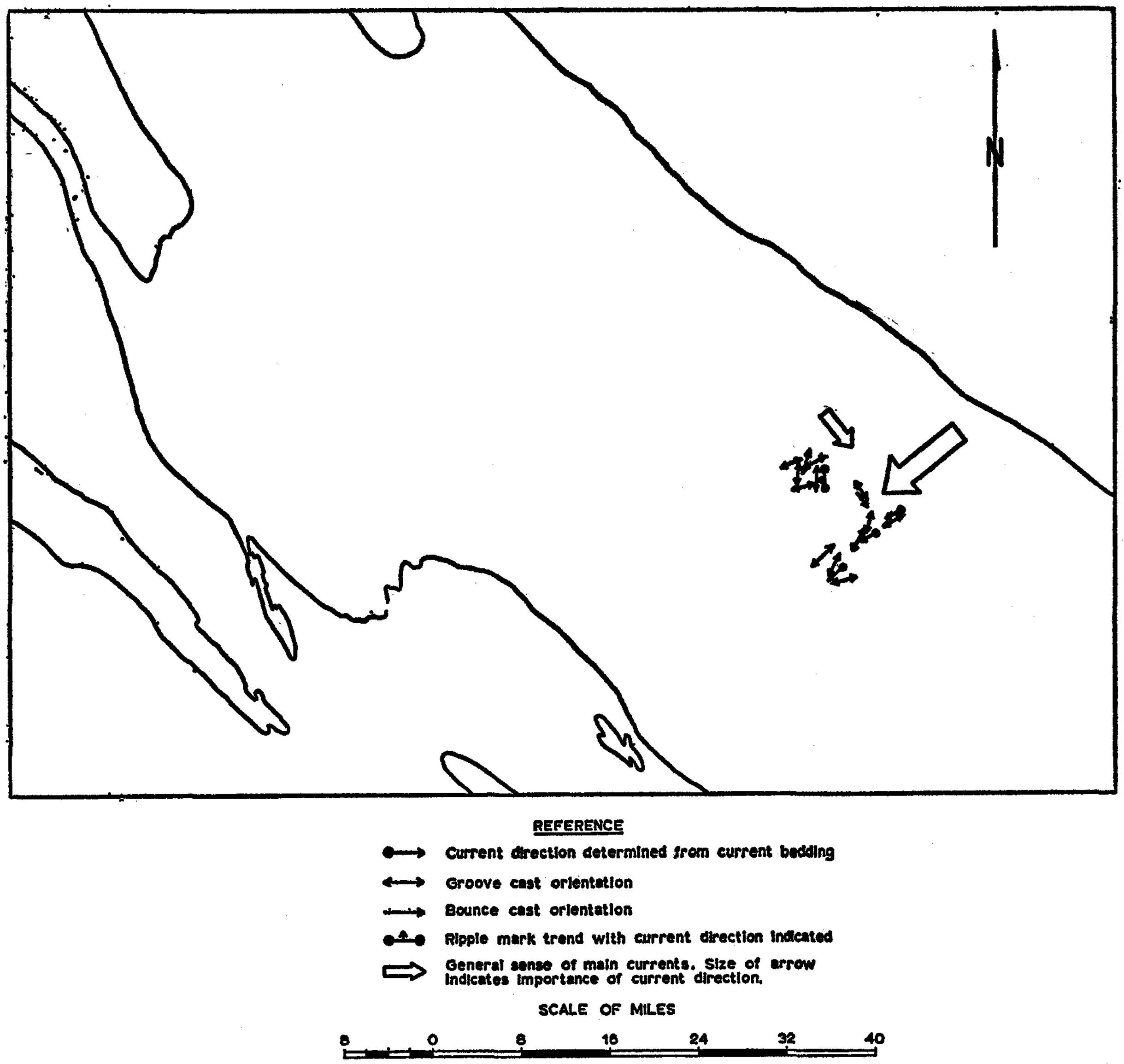

FIGURE 18 PALAEOCURRENT DIRECTIONS FOR FORDS CREEK SHALE

The deposit is the result of a drastic change in conditions. It appears that a major land area to the northwest, north and northeast emerged near the beginning of Coodardoo Sandstone times. The basin apparently had a northwest to southeast elongation and a southeasterly plunge of its main axis.

Fords Creek Shale

Overlying the Coodardoo Sandstone is the Fords Creek Shale composed essentially of a 5,000 feet to 6,000 feet thickness of dark green, maroon, and cream shale with occasional bands of chert, greywacke, and siltstone.

The greywacke forms thin beds between 4 inches and 18 inches thick, is dark-grey to dark greenish-grey and carries frequent clay pellets. The soles usually show abundant erosional structures including groove casts, bounce casts, and flute casts. Current bedding is frequently seen near the shaly top of the bands and parting lineation and ripple marks are commonly observed. Measurements of these linear features indicate a provenance lying to the northwest and northeast (Figure 18). Rare slump structures were also noted and indicate movement of the sediment-mass towards the south.

The period represented by the Fords Creek Shale is one essentially of (?) deep sea shale deposition with the intermittent addition of turbidity current deposits, the material for which having been derived from a land mass to the northwest, north, and northeast.

Kurabuka Formation

This formation consists of a thick sequence of greenish grey shale, dark-grey siltstone, black mudstone, and occasional orthoquartzite beds. It is thought to be several thousand feet thick, but only the lower several hundred feet are present in the Edmund 4-mile Sheet area.

At the base of the formation is a 100-foot-thick quartzite showing current bedding. Current bedded units within this quartzite show that the current came from either the north or the south. Usually, adjacent units show completely reversed current directions. This oscillation type of current bedding could possibly have resulted from tidal activity.

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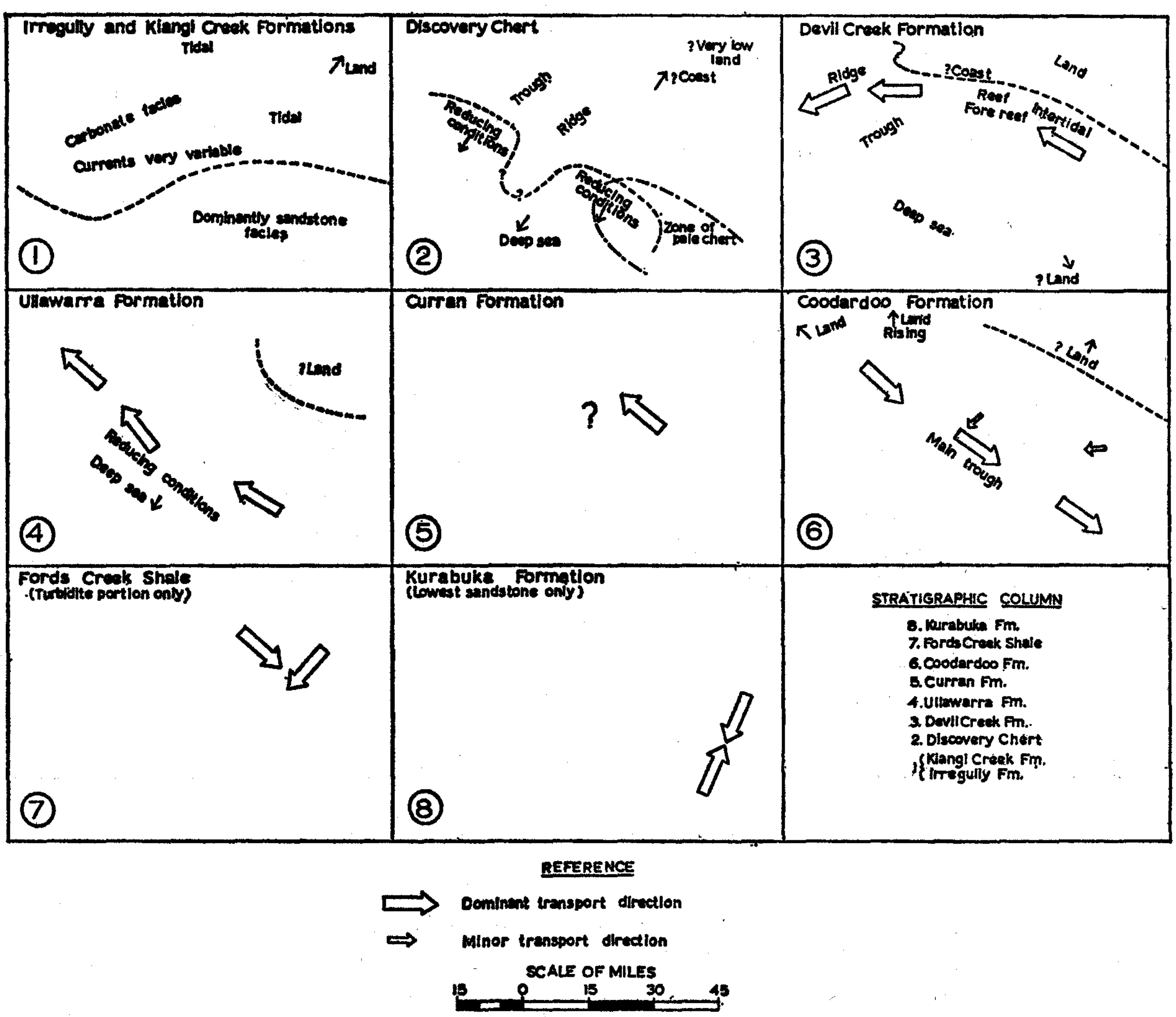
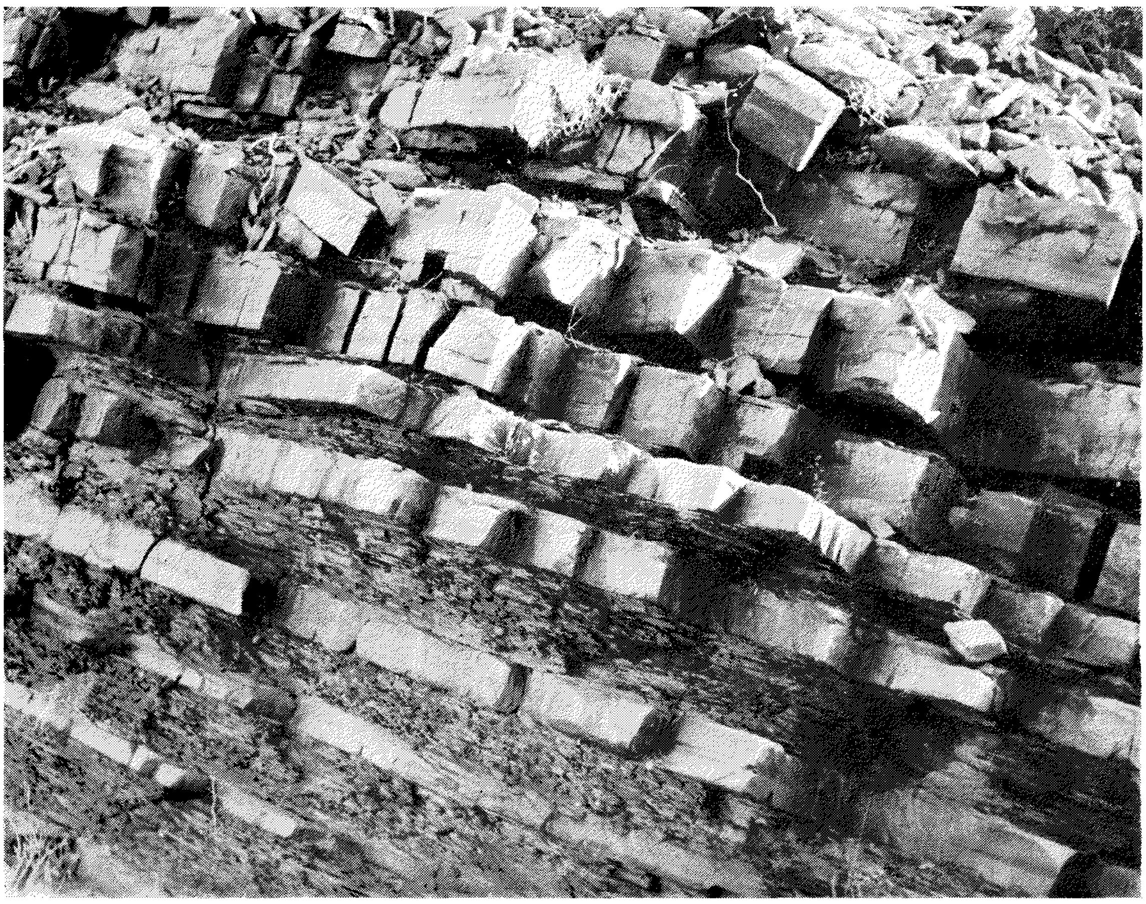
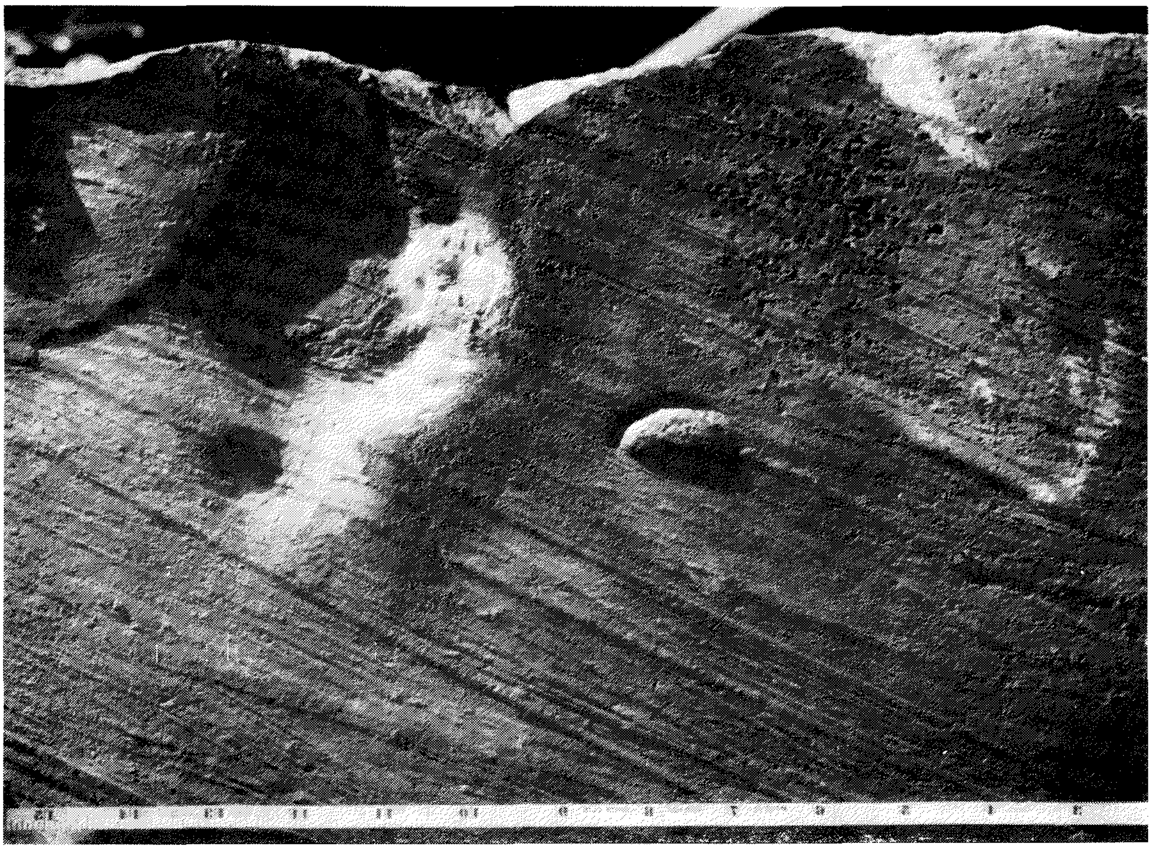


FIGURE 19 SUMMARY OF THE PALAEOGEOGRAPHY OF THE BANGEMALL GROUP EDMUND SHEET AREA

A—Algal stromatolites of *Crytzoon*-type from top of the Irregully Formation, east branch of Henry River.



B—Prominent turbidite bands and shale in "transition zone" between Curran and Coodardoo Formations, ten miles north of Ullawarra Homestead.



A—Large bounce cast with groove casts showing several orientations on sole of turbidite near base of Coodardoo Sandstone. Locality as for Plate 21B.

B—Close-up of sole of turbidite band showing groove casts with several orientations. Locality as for Plate 21B.

SHELL BEDS AND A CHANGE IN SEA LEVEL ALONG THE NORTHWEST COAST OF W.A.

By M. Kriewaldt

ABSTRACT

Beds which contain the taxodont pelecypod *Anadara* c.f. *granosa* (Linne) extend intermittently, and at much the same elevation, along at least 200 miles of the northwest coast of Western Australia. Sample NZ515 of *Anadara* shells from these deposits, 15 feet above Indian Spring low water mark at King Bay near Nickol Bay, gave a radiocarbon age of 2,080±80 years before 1950. The sea level at the time of deposition has not been established but it was possibly at least 2 feet above the present level, assuming a stable land mass.

INTRODUCTION

Along the northwest coast of Western Australia there are sedimentary deposits in which there are many cockle shells. These beds have been mapped at the scale of 1:250,000.

It is thought that the beds were formed some two thousand years ago when the sea level was at least 2 feet higher than now.

The location of these beds is shown in Plate 23: also, five localities where the beds contain the shells are listed in Table 1. Samples from the beds were reported on by Dr. H. S. Edgell in unpublished reports of the Survey. The character and possible significance of these beds was first recognized by Dr. R. C. Horwitz of the Survey in 1962.

DESCRIPTION OF DEPOSITS

The beds with cockle shells extend along the present coast for over 200 miles and also inland for several miles along old creeks. The sediments of the deposits range from loam to sand. At several localities near the present coast the beds interfinger with old beach dunes. The beds are being eroded at present and in places are overlain by younger deposits. Where the surface is eroded by rain wash the shells remain as a mantle. Underlying the beds are extensive beds of clay that form an old plain. Also underlying the beds along the coast of the old plain are old beach deposits cemented into limestone.

Cockle shells from deposits at the Nickol River Crossing have been identified by Mr. G. W. Kendrick of the Western Australian Museum as the taxodont pelecypod *Anadara* c.f. *granosa* (Linne). The *Anadara* shells are generally separated into single shells, but at some localities (such as near Nickol Bay) many are still hinged together. At the south end of the Balla Balla causeway, the deposits are packed full with shells. Elsewhere the shells are widely scattered in the terrigenous matrix. There are also a few shells of other marine pelecypods and gastropods in the deposits and a scattering of land snails.

The elevation of the top and bottom of the beds increases away from the coast. Near the coast the elevation of the top of the beds is about 5 feet above the high tidal flats, whereas inland the top is about 50 feet higher. The bottom of the beds is about 2 feet above the high tidal flats near the coast and rises only a little above this for a few miles inland. Further inland there is no information on the position of the base of the beds.

The beds thicken from only a foot or two near the coast to an estimated 30 feet a few miles inland (for instance at the Nickol River Crossing) and thin out to presumably only a few feet still further inland.

Distinguishable from these older shell deposits are modern accumulations of *Anadara* shells that have been washed and blown into shell banks in backwaters and other traps on the high tidal flats. In addition, some modern *Anadara* shells are blown on to high ground bordering the tidal flats. Also younger than the beds with *Anadara* are the deposits of shells derived from them. These are mainly the surface mantle deposits described earlier. Modern *Anadara* lives in the tidal zone seawards from the mangroves which fringe much of the coast.

Table 1

LOCALITIES OF BEDS WITH *ANADARA* FROM THE NORTHWEST COAST OF WESTERN AUSTRALIA

Description	Thickness	Elevation of base	Latitude	Longitude	Geological Sheet
Between Boodarie and Cape Thouin. G.S.W.A. Field Specimen No. 11465. Collected by G. R. Ryan	Base of old dune	A few feet above high tide level	20° 22·5′ S.	118° 17′ E.	Roebourne
South end of causeway to Balla Balla	About 5 feet	A few feet above high tidal flat	20° 42′ S.	117° 47′ E.	Roebourne
Nickol River Crossing. G.S.W.A. Fossil No. F5050. Collected by R. C. Horwitz	About 20 feet	Possibly 5 feet above high tide level	20° 46′ S.	116° 57′ E.	Dampier
Nickol Bay: 1½ miles northerly along creek from Thirteen Mile Well. Radiocarbon reference No. NZ515	About 2 feet at sample site	A few feet above high tidal flat. 15 feet above Indian Spring low water mark, King Bay	20° 43·5′ S.	116° 47′ E.	Dampier
Surprise Well area, particularly near telephone line. Located by I. R. Williams	Top at plain level	Base not exposed	21° 18′ S.	115° 51′ E.	Yarraloola

Nickol Bay locality

A sample of over fifty *Anadara* shells was picked out of these beds exposed in a creek bank at the locality near Nickol Bay shown in Plate 23.

Surveyors working on the Hamersley Railroad Project have determined the elevations of the beds at the sample locality and nearby. Mr. W. A. Zachry, Project Engineer, provided the following information:

	feet
Elevation of bottom of shell bed 'A'	15.09
Elevation of top of shell bed 'A'	15.87
Elevation of creek beds between 'A' and 'B'	14.49
Elevation of top of shell bed 'B' (460 feet from creek)	16.58

A hole was dug to elevation 14.93 feet at 'B'. The shell continues below this point and is cemented together with sand and crushed shell.

A further bed was found on a ridge as shown on the sketch. Ground elevation of the ridge is 37.78 feet and shell is found lying on the surface and mixed with the red loam down to elevation 33 feet. They probably extend below this point. These elevations are based on a tide gauge in the King Bay area and the datum is Indian Spring low water mark King Bay. The maximum tidal range at King Bay is 15 feet.

The tides along the northwest coast are of the regular semi-diurnal type. The mean tidal ranges for five ports on the coast are shown in Table 2.

Table 2

MEAN TIDAL RANGES

(From Government Astronomer's Tables)

Locality	Range			
	Spring		Neap	
	ft.	ins.	ft.	ins.
Port Hedland	19	3	12	2
Balla Balla	19	0	12	0
Point Samson	18	0	10	0
Fortescue	13	6	8	6
Onslow	8	0	5	0

AGE DETERMINATION

A radiocarbon age determination on the sample of shells from near Nickol Bay was made at the Institute of Nuclear Science New Zealand. The age as at 1950 is 2,080±80 years.

It is quite possible that the deposit from which the sample was collected accumulated within a few years, but there is also the possibility that it may have taken some hundred years or more, in which case the animals now represented by the shells in the sample did not all die within a few years, as the sample was collected without regard to the position of the shells within the deposit. This possibility rules against simply accepting the apparent age of the sample as the age of the deposit.

Dr. T. A. Rafter, Director of the Institute advises that:

1. The sample has been allocated the number NZ515 for publication.
2. The sample was prepared and corrected by the CO_2 proportional counting methods as described by G. J. Ferguson and T. A. Rafter. (See New Zealand Journal of Geology and Geophysics volume 5, pages 332 and 333 for references).
3. The sample was counted for one night, the normal time for most samples, and was preceded and followed by modern standard and background measurements.
4. The age was calculated with respect to ocean water at the latitude of the sample collection site.

ENVIRONMENT

The beds with *Anadara* nearest the coast are thought to have been deposited on an old high tidal flat. It is thought that the shells were washed inland along tidal creeks up onto the tidal flat to be buried there by material brought down by creeks; and that a succession of new surfaces was built upwards. At the beginning these surfaces too were bare tidal flats; while later they were only infrequently inundated by either the sea or by river floods. During seasonal storms it is likely that living animals were swept in and buried, whereas normally disarticulated shells were washed up. Some shells were carried still further inland into the mouths of creeks; and yet others were blown higher before being buried. Such must have been the origin of some of the highest shell-bearing deposits unless the sea was relatively higher at the time of their formation, and if so, some of the topographically higher deposits could be older than the lower deposits.

CHANGE IN SEA LEVEL

Accepting that the beds nearest the coast overlie an old high tidal flat and taking into consideration that the base of the beds near the coast is about 2 feet above the present high tidal flat, then sea level was relatively about 2 feet higher at the time of formation of the flat than at present. This assumes that the coastal morphology at the time was much like that at present, and that the tidal range was the same.

Remembering that the beds interfinger with old beach dunes and that both the beds and dunes are younger than the old high tidal flat, then, with the same assumptions as above, it is reasonable to conclude that sea level at the time of formation of the beds was relatively at least as high as at the time of formation of the tidal flat.

If one more assumption is made, namely, that the landmass is stable, then sea level at the time of formation of the beds was at least about 2 feet higher than at present.

This last assumption has some support in the observation that the beds are at much the same elevation along the coast, which suggests at least a relative stability along the coast. Other factors supporting stability are that no folding, faulting, vulcanicity or glaciation have been recognised in the Quaternary of the adjacent land mass, and that the youngest folding known from anywhere nearby is of Lower Miocene beds.

Taking the "age" of the shell sample as a good indication of the age of the deposit and remembering the uncertainties in establishing the position of sea level at the time, it can be concluded that at some time within say 200 years of 2,080 years before 1950, the sea level was at least about 2 feet higher than at present.

ACKNOWLEDGMENTS

Mr. G. W. Kendrick, Dr. T. A. Rafter and Mr. W. A. Zachry are thanked for their help.

IRON ORE DEPOSIT "A", KOOLYANOBBING, YILGARN GOLDFIELD

by W. N. MacLeod

ABSTRACT

Close drilling of the Koolyanobbing "A" deposit has established indicated reserves of hematite-limonite ore amounting to 4,120,000 tons to a depth of 100 feet below Datum Level. This ore averages 60.0 per cent iron and 0.04 per cent phosphorus. Zones of high phosphorus content are fairly sharply defined from zones of low phosphorus and it would be possible to selectively mine the ore to a grade of less than 0.04 per cent. phosphorus.

Drilling of the canga mantle on the hanging wall of the ore body has established reserves of 700,000 tons of material averaging 59.7 per cent iron and 0.028 per cent phosphorus.

INTRODUCTION

The Koolyanobbing "A" deposit is the current source of hematite-limonite ore for the Wundowie charcoal iron industry. After mining and crushing, ore from the deposit is road-hauled to Southern Cross, thence railed to Wundowie which is situated about 40 miles east of Perth.

The deposit falls within the special mineral lease held by The Broken Hill Pty. Co. Ltd. for the development of the Koolyanobbing iron ore deposits for ultimate use in the Kwinana iron and steel industry. Under an agreement between this company and the Western Australian Government, the Wundowie charcoal iron industry can mine up to 100,000 tons of ore per year from deposit "A". Current production of iron ore from "A" deposit amounts to about 6,000 tons per month and total production to June, 1965, since 1950 when the deposit was first utilized for the charcoal iron industry, amounts to 629,285 tons averaging 62 per cent iron.

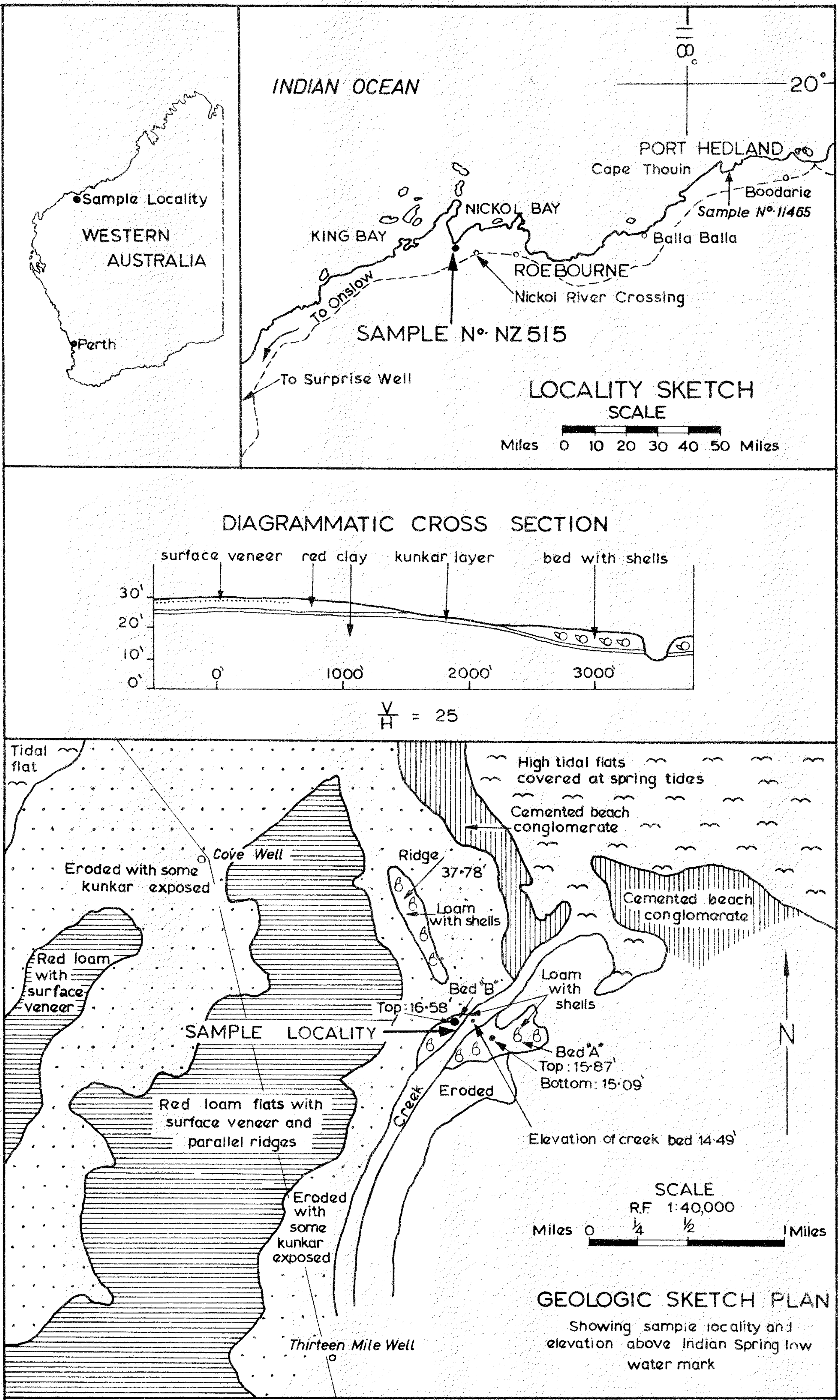
In view of negotiations for sale of the industry to Australian National Industries Ltd., a test drilling programme was undertaken, between August and October, 1965, to gain a more accurate assessment of the grade of ore and the reserves available. Previously the deposit had been mapped and sampled by the Geological Survey in 1938 (Hobson, 1945), drilled by the Mines Department between 1954 and 1955 (Ellis, 1958), and drilled and mapped by The B.H.P. Co. Ltd. between 1960 and 1963. The present drilling programme is supplementary to the drilling by The B.H.P. Co. Ltd. and was planned to test the upper zones of the ore body at fairly close intervals and within the limits of feasible mining depths.

The drilling programme was planned and supervised by W. N. MacLeod and J. Sofoulis of the Geological Survey of Western Australia. The B.H.P. Co. Ltd. supplied all available data from previous company work on the ore body and this was invaluable in planning the drilling programme.

The ore body was sampled in the present test programme with 1,585 feet of percussion drilling in 15 holes supplemented by 960 feet of channel samples on exposed portions of the ore body.

The drilling contractors were Foundation Engineering (Australia) Pty. Ltd. using a Schramm down-the-hole hammer rig. This drill gave satisfactory sample recovery over the greater part of the ore that was tested. The drilling crew was highly competent and spared no effort to obtain the best sample possible.

In all holes the ore was sampled over 5-foot intervals and these samples were analysed by Mining and Agricultural Laboratories, Perth. Duplicate samples from all holes and channel samples were supplied to The B.H.P. Co. Ltd.



GEOLOGICAL SURVEY OF WESTERN AUSTRALIA

NICKOL BAY LOCALITY

RADIOCARBON SAMPLE NZ 515

GENERAL FEATURES OF THE ORE BODY

The Koolyanobbing 'A' deposit is a lens of hematite-limonite ore approximately 2,400 feet long and 125 feet thick. The ore body is resistant to erosion and forms a prominent ridge rising to a maximum of 300 feet above the level of the surrounding plain. The ore lens is concordant with the northwesterly strike of the enclosing schist and jaspilite and dips to the northeast at angles between 45 and 80 degrees (Plate 24).

At the southern end the ore body is terminated by a fault bringing the hematite into contact with unenriched jaspilite. At the northern end the ore appears to grade out laterally into jaspilite. Neither on the hanging wall nor the footwall are there any exposures of the ore—schist contact, except those that have been revealed by quarrying operations. On the footwall there is a thick cover of ironstone scree that extends outwards below the iron ore cliffs for several hundreds of feet. On the hanging wall side of the ore body, up to 70 feet of loose iron scree and canga ore mask the iron ore—schist contact. Accordingly estimates of the thickness of the ore lens are approximate, except in the upper and lower quarries, where both walls have been exposed. In calculations of ore reserves the thickness was determined from measurement across the outcrop and accordingly, the figures quoted are conservative.

The Koolyanobbing 'A' deposit was intersected in three deep holes, well below the level of surface alteration, during the Mines Department drilling programme in 1954-55. These intersections revealed the presence of a magnetite ore zone, with minor schist and greenstone partings, on the hanging wall section of the ore body. Beneath the magnetite zone there is a thick and persistent pyrite lode forming the footwall section of the ore body. This dual character of the ore body in depth finds an expression in the nature of the ore above the zone of oxidation. The magnetite section has been altered by oxidation and hydration to a hematite-limonite ore containing a high content of massive, blue, hematite-rich ore and only a minor amount of residual magnetite. The footwall section, originally composed mainly of pyrite, has assumed the character of a highly ferruginous gossan containing a high content of ochrous, incoherent limonite.

In the existing quarry faces these two principal sections of the ore body can be broadly distinguished on the basis of a relative paucity of hematite in the footwall section. However, there is great variation over short distances in the mineralogical composition and texture of the ore in both sections and it is apparent that the entire ore body has been profoundly modified by protracted supergene alteration through the agency of oxygenated groundwaters. Original lines of weakness in the ore body, such as bedding planes or minor faults in the axial zones or on the limbs of the tight folds, have served as channels of water movement. This intricate structural control of water movement may account for the abrupt and apparently random variations in texture, degree of hydration of the iron oxides, and distribution of minor constituents such as phosphorus and manganese.

THE DRILLING PROGRAMME

The drilling programme previously undertaken by The B.H.P. Co. Ltd. had partly tested both the hematite-limonite ore lens and the canga sheet. No information was available on the nature of the uppermost section of the hematite-limonite ore between grid coordinates 0 feet N. and 1,200 feet N. (Plate 24) as the company drilling in this section had intersected the main ore lens at depths greater than R.L. -100 feet. Two holes (KA. 2A and KA. 5) sited near 1,200 feet N. and 0 feet E. had penetrated the upper section of the ore and indicated a wide range in phosphorus values.

The present programme was planned to test the upper section of the ore lens between 0 feet N. and 1,200 feet N. at approximate intervals of 100 feet, and ten holes were sited and drilled as close as access permitted to the outcrop of the hanging wall of the ore body. These holes were planned to reach either the footwall of the ore body or a R.L. of -100 feet. In several of the holes these targets were not reached due to drilling difficulties. Zones of cavernous limonite in the footwall section prevented air return with consequent loss of sample or, alternatively, the limonite ore was so soft that it filled the hole faster than the air could remove the cuttings. Some of these sections were cased to overcome these difficulties. In some sections exceptionally fine-grained hematite that breaks into coarse angular fragments jammed both hammer and rods.

In general, however, most of the ore sections gave little drilling trouble and adequate samples were obtained over the greater length of most holes.

The canga ore was tested in six holes between 300 feet N. and 1,200 feet N. and a long channel sample (260 feet) was taken along the eastern face of the upper quarry. Channel samples of the hematite-limonite ore were taken across the faces of both quarries, and in three sections of the outcrop of the ore lens at 890 feet N., 1,025 feet N. and 1,100 feet N.

DETAILS OF INDIVIDUAL DRILL HOLES

The position of the drill holes is shown on the accompanying Plate 24 and assay logs of all holes are available at the Geological Survey office (MacLeod, 1965). Samples were taken at 5-foot intervals and assayed at this interval. The assay values were averaged over lengths of 20 feet as this interval is considered to provide a more realistic picture of the variations that can be expected in normal mining practice and bulk sampling during mining.

Holes drilled in this programme have been designated with the code letters WP (Wundowie Percussion) to distinguish them from the earlier B.H.P. holes that are designated KA.

Hole WP.1

Coordinates: 40 feet W, 300 feet N

R.L. of collar: 95 feet

Depth of hole: 100 feet

This hole was sited in the upper quarry and was entirely in hematite-limonite ore. All 5-foot sections assay over 60 per cent iron. From the surface to 20 feet the ore contains 0.064 per cent phosphorus but the average phosphorus content for the entire hole is 0.40 per cent.

Hole WP.2

Coordinates: 5 feet E, 555 feet N

R.L. of collar: 145 feet

Depth of hole: 110 feet

This hole was sited about 20 feet east of the hanging wall outcrop and planned to intersect the main ore lens approximately at the level of the upper quarry floor. Because of a steepening of the dip of the ore lens in this zone (not apparent in examination of the quarry face) the hole was in canga ore from the surface to a depth of 61 feet, then passed into schist which was followed down to 110 feet before the hole was abandoned. The canga in this section is of lower grade than normal and contains more silica, lime and magnesia than was encountered elsewhere.

Hole WP.3

Coordinates: 75 feet W, 660 feet N

R.L. of collar: 153 feet

Depth of hole: 147 feet

Canga and uncemented ironstone rubble were encountered in the uppermost 25 feet of the hole. From 25 to 130 feet the hole was in limonitic ore averaging about 58 per cent iron. Phosphorus and manganese are low in most sections of the hole. At 130 feet the hole passed into schist and remained in schist until abandoned at 147 feet. This schist band may be a continuation of the thick band encountered in Hole WP. 15.

Hole WP.4

Coordinates: 70 feet W, 750 feet N

R.L. of collar: 153 feet

Depth of hole: 170 feet

This hole was in predominantly limonitic ore averaging about 57 per cent iron for the first 50 feet below surface. From 50 to 170 feet the ore is rich in hematite with most sections assaying higher than 65 per cent iron. Phosphorus and manganese are low in all sections of the ore in this zone. No schist bands were intersected in this hole.

Hole WP.5

Coordinates: 20 feet W, 890 feet N
R.L. of collar: 130 feet
Depth of hole: 193 feet

For the uppermost 5 feet the hole passed through low-grade rubble rich in lime and was in limonitic ore of variable grade until 50 feet. Thin schist bands occur in the zone between 40 and 50 feet. From 50 feet to the end of the hole the ore is rich in hematite with some sections assaying over 67 per cent iron. A high-phosphorus section occurs between 45 and 85 feet. Over this length the ore averages 0.057 per cent phosphorus with individual 5-foot sections ranging as high as 0.079 per cent.

An exceptionally rich manganese section was cut between 145 and 165 feet with an average of 1.13 per cent manganese rising to 2.13 per cent in the section between 150 and 155 feet. For the entire hole, however, the phosphorus and manganese contents average below the required limits of 0.04 per cent phosphorus and 0.40 per cent manganese.

Hole WP.6

Coordinates: 35 feet W, 1,025 feet N
R.L. of collar: 126 feet
Depth of hole: 155 feet

From the surface to 20 feet the hole was in low-grade canga and rubble with an iron content of less than 50 per cent and a phosphorus content of 0.064 per cent. From 20 to 65 feet the ore was mainly limonitic until passing into schist bands between 65 and 75 feet. Below 75 feet there is an abrupt transition into a hematite-rich ore averaging about 63 per cent iron but containing a large amount of phosphorus with most 5-foot sections assaying over 0.10 per cent. This section grades off into lower phosphorus values below 125 feet and in the lowermost 30 feet of the hole the phosphorus values are less than 0.03 per cent. Manganese content is highly variable in this zone of the ore body with values ranging from 0.002 per cent to 0.22 per cent.

Hole WP.7

Coordinates: 10 feet W, 1,100 feet N
R.L. of collar: 107 feet
Depth of hole: 110 feet

Between the surface and 25 feet the hole passed through canga ore averaging about 52 per cent iron with exceptionally high phosphorus content. The section between 5 and 10 feet contains 0.32 per cent phosphorus and the 25-foot section of canga averages 0.17 per cent phosphorus. Below 25 feet the hanging wall zone of the ore body was intersected and high phosphorus values are maintained to a depth of 80 feet. Schist bands were cut between 94 and 95 feet, 95 and 97 feet and 100 and 104 feet. The hole was terminated in hematite—limonite ore with low phosphorus at 110 feet. The average phosphorus content for the entire section is 0.09 per cent. Manganese values are very low in all 5-foot sections.

Hole WP.8

Coordinates: 0 feet W, 1,300 feet N
R.L. of collar: 76 feet
Depth of hole: 100 feet

This hole was in canga between 0 and 15 feet but remained in hematite—limonite ore until terminated at 100 feet. Thin schist bands were cut between 45 and 50 feet. Low phosphorus and manganese values were found in all 5-foot sections of the ore.

Hole WP.9

Coordinates: 125 feet E, 1,170 feet N
R.L. of collar: 79 feet
Depth of hole: 45 feet

This hole was in canga from the surface to 20 feet, beyond which it intersected a mixed low-grade rubble of canga and schist. It is apparent that the canga sheet thins rapidly to the north beyond this hole.

Hole WP.10

Coordinates: 90 feet E, 810 feet N
R.L. of collar: 111 feet
Depth of hole: 37 feet

This hole was sited between the B.H.P. holes KA.4 and KA.6 to test the canga ore in this zone. The hole was abandoned at 37 feet because of a broken hammer jammed in the hole. The ore in this section averages 58.6 per cent iron and 0.046 per cent phosphorus.

Hole WP.11

This hole was sited about 100 feet downslope from KA.4 but was not drilled as the available earth moving equipment was inadequate for the preparation of an access track.

Hole WP.12

Coordinates: 130 feet E, 285 feet N
R.L. of collar: 129 feet
Depth of hole: 53 feet

This hole was sited near the southern end of the canga sheet to test the thickness and grade of canga in the zone behind the eastern face of the upper quarry. The hole had to be abandoned in cavities at 53 feet before the full thickness of canga had been penetrated. The canga in this section is of higher grade than normal, averaging 62.5 per cent iron and 0.03 per cent phosphorus.

Holes WP.13 & 13A

Coordinates: 150 feet E, 480 feet N (WP.13A);
150 feet E, 490 feet N (WP.13).
R.L. of collar: 112 feet
Depth of holes: 15 feet (WP.13A), 80 feet (WP.13).

Hole WP.13A was drilled to 15 feet and had to be abandoned because of badly caving ground at 15 feet. The drill rig was shifted 10 feet north and hole WP.13 drilled to a depth of 80 feet without encountering the same difficulty. The hole passed into schist at 79 feet and this is the maximum thickness of canga ore recorded during the drilling programme. The canga in this section averages 59.3 per cent iron and 0.016 per cent phosphorus.

Hole WP.14

Coordinates: 10 feet W, 1,495 feet N
R.L. of collar: 39 feet
Depth of hole: 150 feet

This hole intersected a siliceous zone between 10 and 15 feet and schist between 44 and 49 feet. Below 125 feet in the footwall zone of the ore body, the ore was cavernous and could not be sampled. Over the entire length of the hole the phosphorus values are abnormally high, averaging 0.03 per cent from the surface to 125 feet. Below 55 feet most of the ore is rich in hematite, particularly in the section between 60 and 90 feet where the iron content averages about 66 per cent. The manganese content of the ore is higher than average in the lowermost 20 feet of the hole.

Hole WP.15

Coordinates: 10 feet W, 500 feet N
R.L. of collar: 93 feet
Depth of hole: 120 feet

This hole was sited close to the northern face of the upper quarry in the hanging wall zone of the ore body. The hole passed into schist at a depth of 53 feet below the quarry floor. This schist band must be intercalated with the ore and is not the hanging wall schist encountered in the nearby hole WP.2. The hole remained in schist to a depth of 120 feet when the hole was terminated.

This is the thickest schist band intersected in any drill hole. On the assumption of a dip of 75 degrees the schist band must be at least 15 feet thick.

The hematite—limonite ore in this hole has high phosphorus values (0.10 per cent) in the section between 20 and 40 feet. The section 35 to 40 feet contains 0.33 per cent phosphorous. Despite these high values the average phosphorus content of the ore over the length of the hole in the ore section is 0.055 per cent.

CHANNEL SAMPLING

To supplement the drilling programme, the hematite-limonite ore body and canga zone were channel sampled in areas of continuous exposure. Channel samples were taken across the hematite-limonite ore in both upper and lower quarries (samples UQF and LQF); the canga ore in the eastern face of the upper quarry (UQC), and in three sections across the hematite-limonite ore body near holes WP.5, WP.6 and WP.7 (samples XS5, XS6 and XS7 respectively). The results of all channel sampling are available at the Geological Survey office (MacLeod, 1965).

Sample UQF

Seven 20-foot channel samples covering the entire width of the ore face in the upper quarry gave a range of iron content from 58.4 per cent to 64.0 per cent. Phosphorus is below 0.04 per cent in all samples and averages 0.018 per cent across the full face. The manganese content of the ore between 0 and 20 feet reaches 0.52 per cent but for the remainder of the section across to the footwall the manganese content is less than 0.1 per cent and averages 0.14 for the entire face.

Sample UQC

Thirteen 20-foot channel samples along the face of canga ore on the eastern side of the upper quarry give a range in iron content between 56.8 and 64.4 per cent with an average value of 61.1 per cent Fe. Phosphorus is below 0.04 per cent in all samples and the manganese content of the material over the entire section averages 0.06 per cent. From these results it can be seen that the canga ore in the upper quarry is of comparable grade to that of the hematite-limonite ore in the main ore body.

Sample LQF

The full width of the hematite-limonite ore body was sampled with nine 20-foot samples and two 10-foot samples in the ore face exposed in the lower quarry. The iron content ranged from 58.0 to 64.6 per cent. High phosphorus values occur in the 40 feet of ore immediately above the footwall with an average of 0.07 per cent. High manganese values, averaging 0.74 per cent, occur in the section between 40 and 80 feet above the footwall. The general run of manganese values in the lower quarry is higher than is normal for the ore body and amounts to 0.25 per cent.

Samples XS5, XS6 and XS7

High phosphorus values were encountered in the drill hole sections in holes WP.5, WP.6 and WP.7. To check the continuance of these zones in an up-dip extension, channel samples were taken across the surface of the ore body at each of these holes. The phosphorus values in channel sample XS5 average 0.056 per cent, compared with the average phosphorus content of 0.035 in the corresponding hole WP.5. For channel samples XS6 and XS7 the the average phosphorus values were 0.05 per cent compared with values of 0.065 per cent and 0.088 per cent for holes WP.6 and WP.7 respectively. No precise correlation could be made between the individual high-phosphorus sections in the boreholes and the higher phosphorus sections in the surface channel samples.

It is worthy of note that the canga ore immediately overlying the ore body in this section of the deposit has abnormally high phosphorus values and this is presumably a reflection of the generally higher tenor of phosphorus in this zone of the parent ore lens from which the canga is derived.

CONCLUSIONS

The additional drilling and sampling of the Koolyanobbing iron ore deposit "A" has confirmed the previously suspected characteristics of the ore body. Along the tested length of the ore lens the iron content is mainly within the range of 60 to 62 per cent, a figure which corresponds closely with the average of the ore that has been mined over the past fifteen years. There are restricted zones of massive blue ore consisting of almost pure hematite and assaying over 67 per cent iron. These zones are impersistent both laterally and vertically as the degree of hydration of the ore has been determined by structural factors of bedding and faulting. As a general rule the proportion of limonite tends to increase on the footwall side of the deposit, and this could be anticipated in view of the known structure of the ore body at depths below the water table.

The phosphorus and manganese contents of the ore have a wide and apparently random variation. Much closer sampling and chemical study of the ore body would be necessary to reveal any controls of these variations. It was noted in some drill holes that there is often an abrupt change in phosphorus content across a schist band. It is conceivable that the phosphorus is transported and re-distributed by groundwater and if this is so, the schist bands could exercise an important control on groundwater movements and localized precipitation of minor elements.

A histogram showing the range and relative distribution of phosphorus values (Figure 20) indicates that the phosphorus content is less than 0.05 per cent in 75 per cent of the analysed samples and less than 0.04 per cent in 65 per cent of the samples. The peak of phosphorus values above 0.10 per cent indicates that there must be some specific structural control within the ore body that, when operative, favours an abnormally high concentration of phosphorus. The values below 0.10 per cent phosphorus follow a normal pattern of distribution with a peak between 0.025 per cent and 0.035 per cent.

High phosphorus values occur over limited intervals in all bore-hole sections. However, the average values over the greater intervals dealt with in normal mining practice fall within or close to the required limit of 0.04 per cent in the larger part of the ore body. The drilling has indicated the existence of two zones in the ore body where the phosphorus values are high enough over a sufficiently large interval to have a detrimental effect on bulk mining grade.

The first of these high-phosphorus zones occurs between 950 feet N and 1,200 feet N where the average value is 0.07 per cent phosphorus. The second zone is near the northern end of the ore body at 1,500 feet N where a 125-foot thickness of ore averages 0.13 per cent phosphorus (Plates 24 and 25). The phosphorus values in the first zone are not so abnormal as to preclude utilization of the ore by suitable blending with low-phosphorus ore from other parts of the ore body.

The restricted zones of high-manganese ore are usually small enough to be mined with the general run of ore without raising the manganese content above the required limit of 0.4 per cent. High manganese values (over 1 per cent) were found in hole WP.5 over an interval of 10 feet, but these are exceptional.

Composite assays of bulk samples show a range in silica content within the general limits of 2 to 8 per cent. Alumina in all samples is less than silica and the average silica/alumina ratio is about 2 to 1. Sulphur is normally less than 0.05 per cent. The content of combined water varies widely with the proportion of limonite in the ore but can normally be expected to be between 7 and 11 per cent.

Schist bands were cut in practically all drillholes in the hematite—limonite ore. These are often only a few inches thick and constitute such a proportionately small volume that they are not detrimental to bulk mining grade. A thick schist band was cut in hole WP.15 near the present upper quarry face at a depth of 53 feet below the present quarry floor. This band must be at least 15 feet thick and will have to be selectively mined when this depth is reached.

In view of the general satisfactory grade of the canga ore it would seem logical to include some of this ore in the future mining of the ore body. Face sampling of the eastern face of the upper quarry and drilling behind this face have indicated a substantial tonnage of ore of requisite specification.

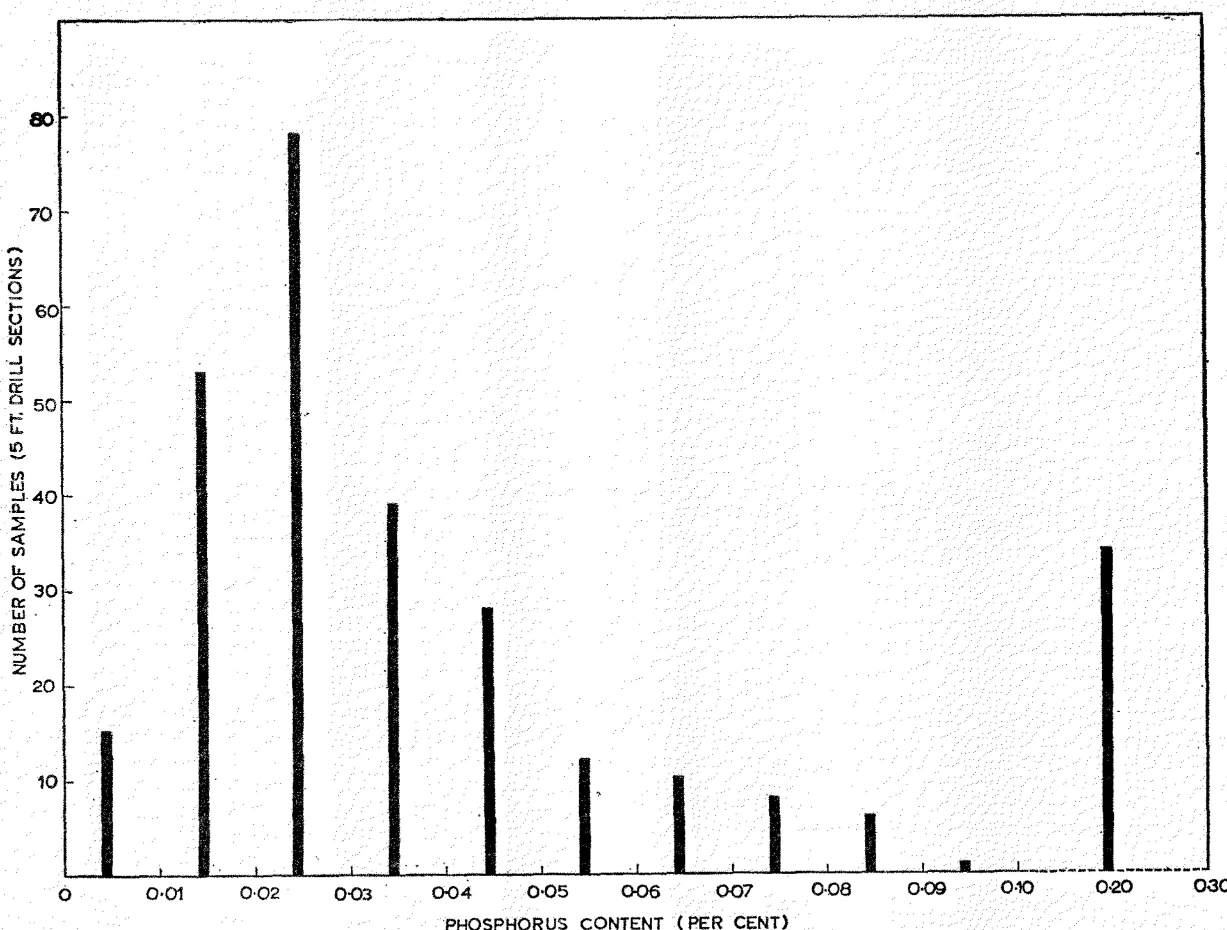


FIGURE 20

HISTOGRAM SHOWING RANGE OF PHOSPHORUS CONTENT IN HEMATITE-LIMONITE AND CANGA ORES (284 SAMPLES)

Progressive removal of the canga from the hanging wall of the hematite—limonite ore body will permit the ultimate development of a long face along the hematite ore body in contrast to the transverse face that is now operated. The opening of a long face along the strike of the ore body permits much greater opportunity for mining to a specific grade, and will allow the selective mining and blending of high phosphorus ore beyond 900 feet N.

Indicated reserves of ore for different sections of the ore body are given in Table 1. Within the limits of the tested area the total indicated tonnage amounts to 4,800,000 tons to a depth of R.L.-100 feet. This figure includes 700,000 tons of canga. The indicated reserves to a depth of R.L.-20 feet amount to 3,200,000 tons of which 700,000 tons is canga. Between coordinates 0 and 900 feet N and to a depth of R.L.-20 feet there are 2,400,000 tons of ore; enough to sustain operations on the present scale for a further 20 years at least.

Table I

INDICATED ORE RESERVES—KOOLYANOBBING IRON ORE DEPOSIT "A".

Ore Block	Surface Area (square feet)	Average Depth of Ore		Tonnage		Average Grade		
		To RL-20 ft. (feet)	To RL-100 ft. (feet)	To RL-20 ft. (tons)	To RL-100 ft. (tons)	Fe %	P %	Mn %
No. 1 (0′–100′ N)	18,200	80	160	145,000	290,000	62·3	0·035	0·20
No. 2 (100′–500′ N)	64,900	115	195	745,000	1,260,000	60·0	0·024	0·10
No. 3 (500′–900′ N)	46,700	170	250	795,000	1,165,000	60·6	0·027	0·02
No. 4 (900′–1200′ N)	32,200	140	220	450,000	710,000	62·3	0·055	0·06
No. 5 (1200′–1600′ N)	40,700	90	170	365,000	690,000	58·3	0·082	0·07
Canga	150,000	70		700,000		59·7	0·028	0·11

Total Indicated Reserves To R.L.-20 ft. 3,200,000 tons
To R.L.-100 ft. 4,820,000 tons.

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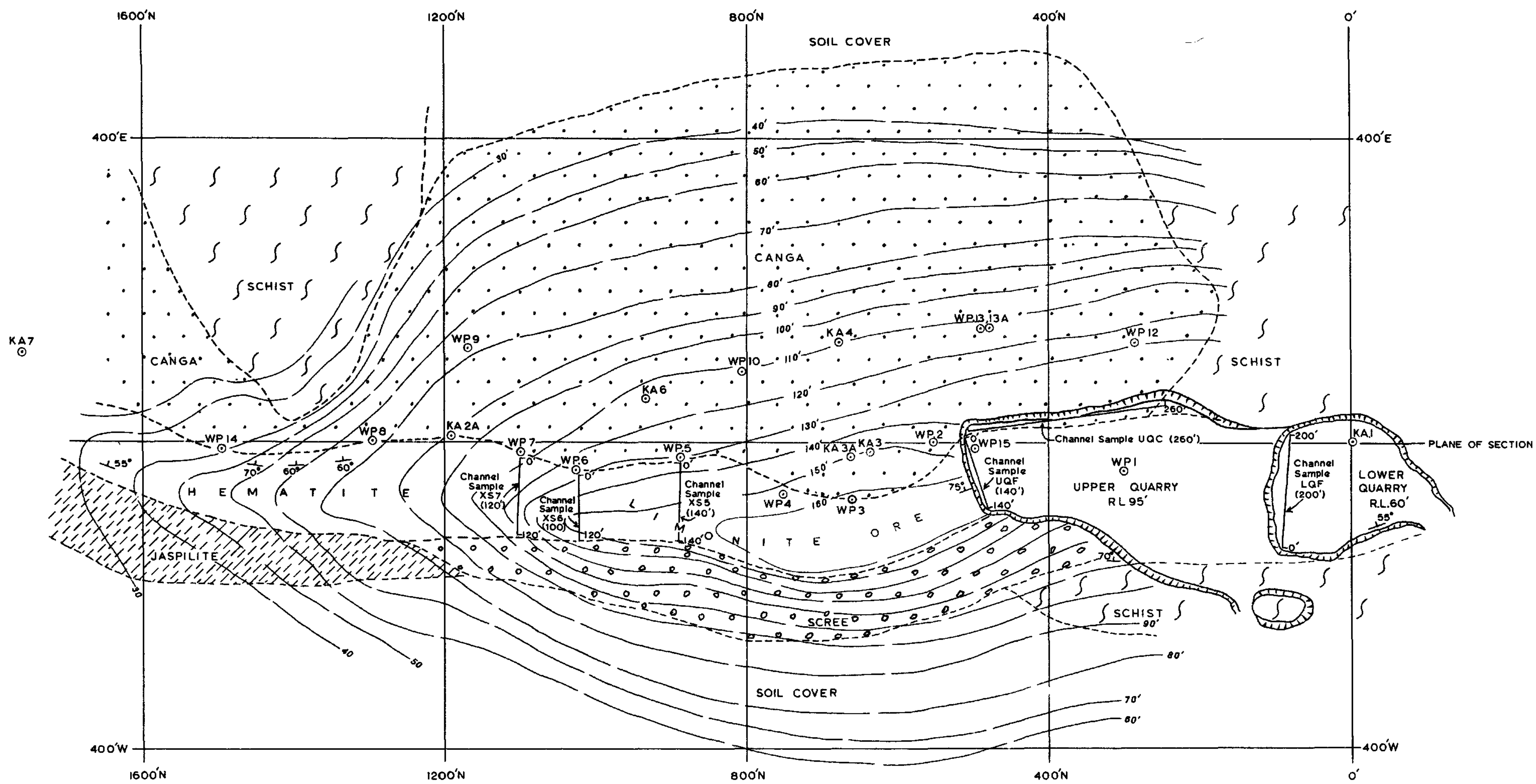
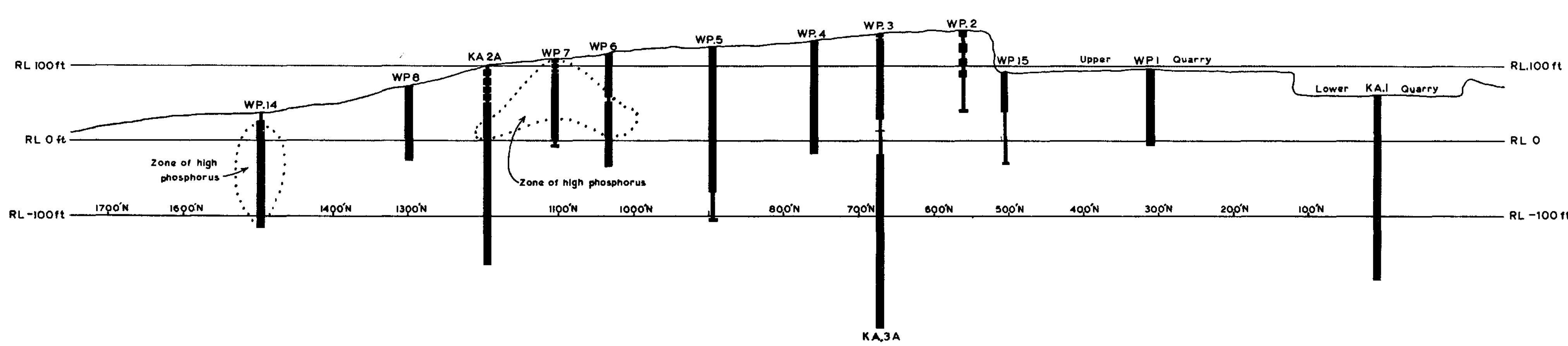
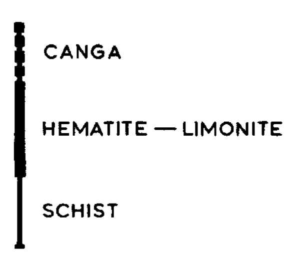




HOLES PROJECTED ON VERTICAL PLANE OF BASE LINE

REFERENCE



GEOLOGICAL SURVEY OF WESTERN AUSTRALIA

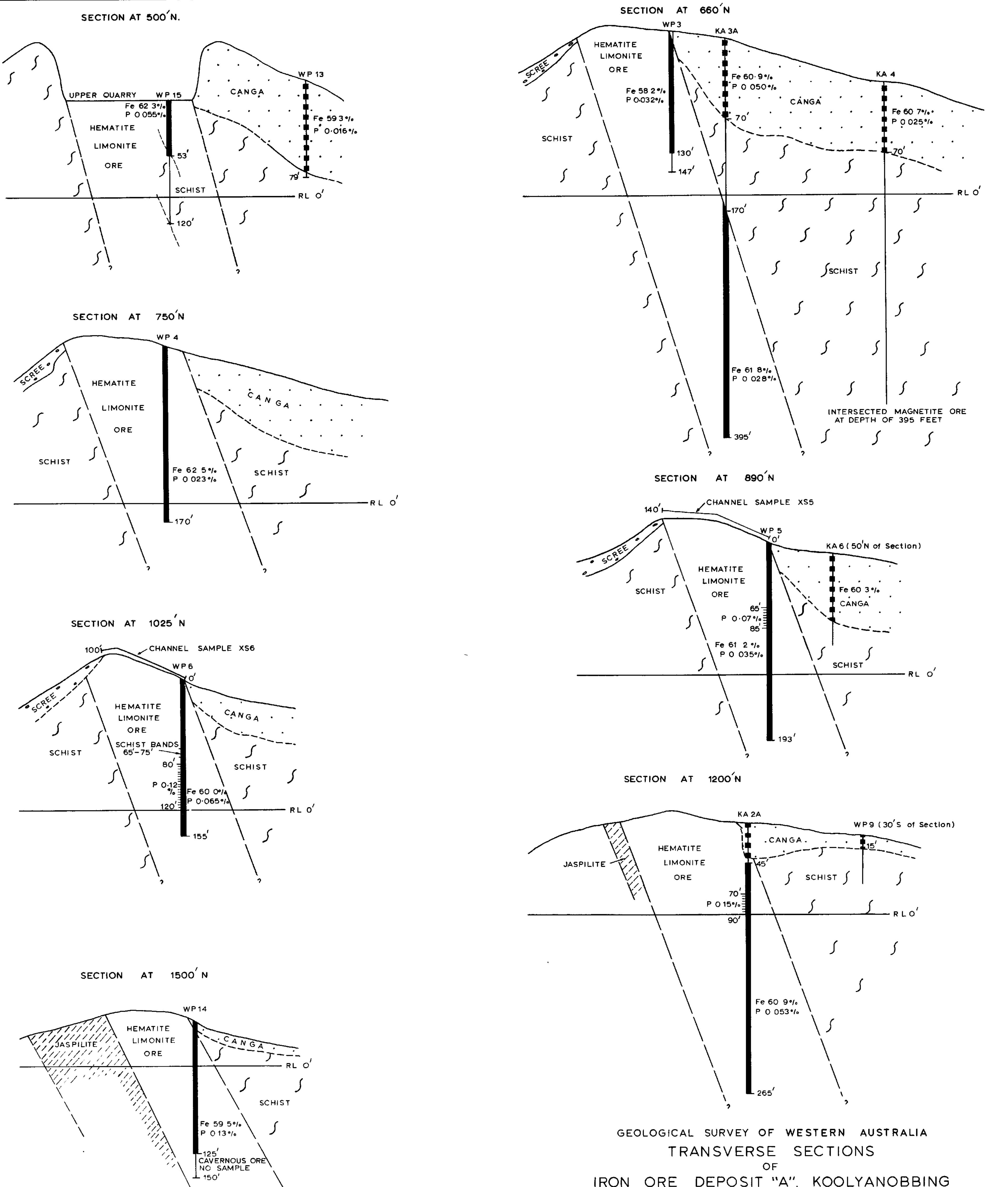
PLAN AND LONGITUDINAL SECTION OF IRON ORE DEPOSIT "A" KOOLYANOBBING

SCALE OF FEET

100 0 100 200 300 400 500

Mapped by W.N.MacLeod & J.Sofoulis G.S.W.A., Sept.1965, with additional information from The B.H.P. Co. Ltd.
Levels based on G.S.W.A. datum.

PLATE 25



GEOLOGICAL SURVEY OF WESTERN AUSTRALIA

TRANSVERSE SECTIONS

OF

IRON ORE DEPOSIT "A", KOOLYANOBBING

9023

A DEPOSIT OF ILMENITE-BEARING SAND AT BOODANOO, 45 MILES SOUTHEAST OF MT. MAGNET

by L. E. de la Hunty

ABSTRACT

A million tons of sand with an ilmenite content of 10 to 20 per cent and several million tons of 5 to 10 per cent material are inferred. Ilmenite and leucoxene are the only commercial minerals in the sand which cannot be classed as ore under the present economic conditions; the ilmenite content is too low and the deposit is too far from the coast (250 miles).

The source rocks are basic igneous rocks and granite. Lake Boodanoo is the centre of a closed drainage system and this is a significant factor in the retention of detrital ilmenite. The concentration of ilmenite is effected by wind action, mostly from the northwest, on lacustrine and eolian sand. Locally there are black skins of ilmenite sand, with a gradual decrease of ilmenite content with depth.

INTRODUCTION

Temporary Reserve 3160H, 45 miles southeast of Mt. Magnet, is held by W. H. Ranken for ilmenite, rutile, zircon, and monazite. The reserve covers 350 square miles and includes lake country on Challa, Meeline and Boodanoo Stations. Its western boundary extends 35 miles north from a point 10.3 miles, 193° from Boodanoo trig. station in the Yalgoo Goldfield and crosses the southern boundary of the Murchison Goldfield at 22½ miles.

Meeline and Challa homesteads are connected to Mt. Magnet by graded roads, but access to the reserve by the numerous station tracks is restricted especially in winter because of the many lakes and claypans.

The nearest railway siding is Mt. Magnet, which is 205 miles from the port of Geraldton.

FIELD WORK

Since the area was applied for, it has been visited by geologists from La Porte Titanium (Aust.) Ltd., The Broken Hill Pty. Co. Ltd., and Western Titanium N.L. Surface investigations have also been made by Mr. Ranken who had analyses made of ilmenite-bearing sands from 1½ miles south of Boodanoo trig. station. Up to the time of this investigation in May 11-14, 1965, no sample pits had been dug.

One day was spent in the company of Mr. E. J. Wade, who was a partner in the venture at that stage, investigating what were thought to be the best deposits. Samples were taken from these and other localities (see Plate 26), and several geological traverses were made. The remainder of the geology was interpreted from aerial photographs.

PHYSIOGRAPHY

The area is in the physiographic division known as Salinaland (Jutson, 1950), and Lake Boodanoo is similar to other salt lakes in this division. It consists of migrating claypans with dunes of sand and kopi. The lake extends northwards for 30 miles and has a maximum width of about 5 miles.

Morgan (1965) has shown that the lakes in Salinaland are in three drainage systems. In his Figure 4 he has shown the divide between rivers flowing westerly to the coast and those flowing southeasterly to "an old coast near Zanthus". However, a divide may be followed south through Anketell and east of Lake Boodanoo, revealing a small closed drainage system of about 3,000 square miles. This small system must have been a part of one of the three major systems, probably draining south into the Avon River, via Lake Moore.

Tilting the West Australian shield to the southeast, as proposed by Morgan, would not have isolated the Boodanoo drainage system so it seems that the closure was effected by some localized warping within the shield itself. Although the drainage is mature within the basin, there is some headward erosion by the streams flowing into the lake from the north, west and east.

There are sandplain remnants of the old plateau in the western part of the area. Some of the hills, such a Boodanoo Hill were monadnocks above the old surface.

Most of the gypsum deposits associated with salt lakes in Western Australia are on the southeastern shores of the lakes, and have been blown there by northwest winds (de la Hunty and Low, 1958). In this area, there are kopi (flour gypsum) dunes and banks on the southeastern shores of the claypans, also sand dunes. Deflation of the northwestern shores, together with infilling of the southeastern part of the claypan by eolian sand and gypsum, causes upwind migration of the claypans to the northwest.

WATER SUPPLIES

The pastoral country has limited supplies of potable water, and there is no reliable surface supply because most of the lakes are dry for the greater part of the year, so it would be preferable to use saline water for any proposed wet treatment of the ilmenite sand. Such water is available in the clay bed of the lake, but the yield from it would be small unless a bore chanced to intersect a sand lens.

Suitable dams could be excavated in the lake and the clay walls built up above the level of the lake floor to form large tanks. Water could then be pumped into the tanks from the surrounding lake during the wet season.

Better quality water (brackish to potable) is available in an outwash fan on the eastern side of Lake Boodanoo. The fan is about 5 miles wide where it meets the belt of eolian sand, 5 miles east of Boodanoo trig. station and it narrows to a mile in width about 5 miles upstream to the east. The prospects for plentiful supplies of underground water in this roughly triangular area are very good. Several other stream outwash areas around Lake Boodanoo also offer good prospects for underground water.

GENERAL GEOLOGY

The Archaean basement rocks of the area are basic igneous rocks with associated sediments, granite, and gneiss, all of which are intruded by quartz reefs. The basic igneous rocks have been intruded by quartz-feldspar-biotite granite. The associated gneiss locally contains abundant garnet and includes many basic lenses.

Sand, clay, and kopi obscure the rocks in the vicinity of Lake Boodanoo but it is likely that the lake is underlain by basic igneous rocks and gneiss, in a north-plunging syncline.

The soft cover-rocks are the only post-Archaean rocks in the area and they are of Cainozoic age. The units mapped include eolian sand, ilmenite-bearing sand, kopi, clay, outwash, and sandplain.

The sandplain and the sandy outwash do not contain much ilmenite but the eolian sand around and over the lake has ilmenite and other heavy minerals dispersed through it, with some local concentration. These heavy minerals, together with quartz sand and clay, have been washed into the lake by streams and floods, and then resorted by wind.

The sand dunes are generally less than a mile long, up to 30 feet high and about 10 chains wide. The heavy minerals are dispersed through the dunes (and the interdunal areas) with occasional black bands of grain thickness. Skins of black minerals, generally less than an inch thick, appear on some dunes and around the edges of some claypans. Concentrations of black minerals occur in runnels on, and issuing from, basic igneous rocks, indicating that the ilmenite has weathered from the basic rocks. This has been confirmed by analysis, although the amounts of ilmenite in the two samples submitted are surprisingly low. A granite sample also contains some ilmenite.

Some of the kopi dunes are more than 20 feet high with local developments of a thin crust of lime carbonate. The kopi dunes are probably older than the eolian sand which overlies low kopi banks in the more open areas of the lake.

ILMENITE CONCENTRATION

Fourteen sand samples and three rock specimens from the area were analysed by the Government Chemical Laboratories (see Table 1). The heavy minerals identified in the sands were: ilmenite, leucoxene, magnetite, non-magnetic iron oxides, and silicates such as pyroxenes, amphiboles, epidote, also traces of zircon and rutile.

The richest concentrations of ilmenite (and other heavy minerals) were in the deposits about 1½ miles south of Boodanoo trig. station. Most of the other samples contained "average" amounts of ilmenite for the area. With the exception of sample No. 2620, the black surface veneer of heavy minerals was avoided when sampling, and the average depth of sampling was 2 feet.

Table 1

ANALYSES OF SAND SAMPLES

Sample No.	Depth of Sample	Heavy* Minerals	Il-menite	Leu-coxene†	Mag-netite	Titanium Dioxide TiO_2
		Per cent. of original sample				
2612	1 ft.	14	8	1	3	6·59
2613	1 ft.	14	8	1	2	6·10
2614	1 ft.	11	6	1	2	5·09
2615	3 ft.	10	2	1	2	2·43
2616	Surface	21	5	1	4	5·21
2617	2 ft.	18	4	1	4	4·91
2618	3 ft.	16	8	1–2	3	6·64
2619	2 ft.	14	7	1	3	5·97
2620	Surface 1 in.	63	41	5–10	4	25·7
2621	2 ft.	32	13	3	3	10·8
2622	4 ft.	24	10	3	2	8·72
2623	2 ft.	36	17	2–4	4	12·4
2627	0–6 ins.	13	1	1	2	2·21
2628	2 ft.	17	6	2	3	4·61

* Specific gravity greater than 2·85.
† Estimated.

Note : The three rock specimens (Nos. 2624, 5, 6) contained traces only of ilmenite, leucoxene and magnetite.

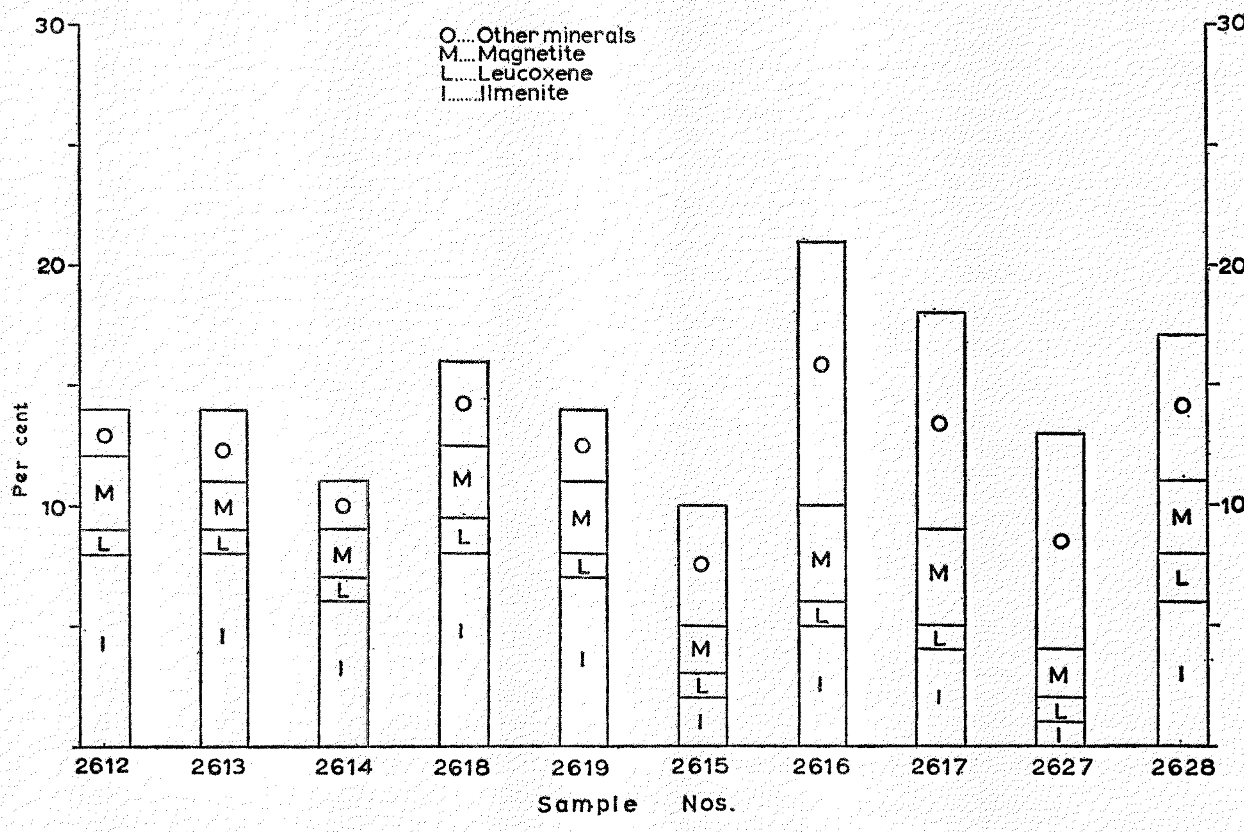


Fig.21 Heavy mineral composition of some sand samples from Boodanoo area.

Excluding the higher values for samples Nos. 2620-3, an average background grade for the remainder of the samples is 14.8 per cent of heavy minerals. This is made up of 5.5 per cent ilmenite, 1 per cent leucoxene, 3 per cent magnetite, and 5.3 per cent others. The areas mapped as 'ilmenite-bearing sand' may contain more than 5 per cent ilmenite but the sampling interval is far too wide to enable any reliable assessment to be made. However, it can be seen from Figure 21, that all of the samples from the southern part of the area contain more than the average concentration of ilmenite, and those from the north have a low ilmenite content. Also, samples from the northern end have a much higher proportion of 'other' minerals in the heavy fraction. For the purpose of this report, the cut-off between "eolian sand" and "ilmenite-bearing sand" is taken as 5 per cent ilmenite.

Figure 22 is a graphical comparison of the heavy mineral composition of the samples with an ilmenite content above 10 per cent. Sample No. 2620 is probably the richest material in the area. It was skimmed from the top of a deposit which itself appears to contain the highest grade sand available. There is a pronounced decrease of grade with depth, from sample Nos. 2620 to 2621 to 2622, and it is likely that the material only 3 inches deep in the pit from which these samples were taken would contain less than 20 per cent ilmenite. Excluding the skin concentration, the average grade indicated by the sampling of these deposits is: 31 per cent heavy minerals consisting of 13 per cent ilmenite, 3 per cent leucoxene, 3 per cent magnetite, and 12 per cent others.

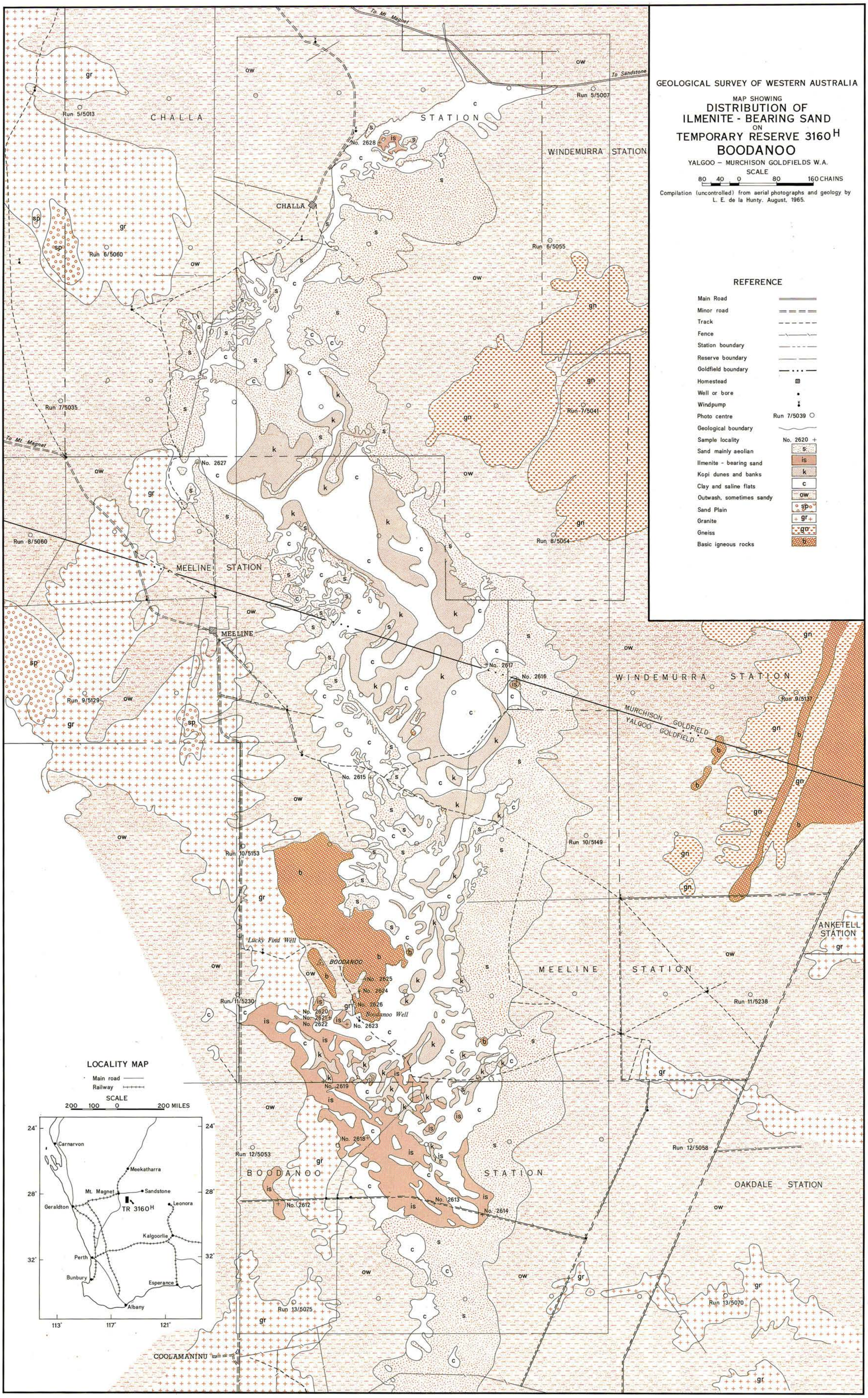

GEOLOGICAL SURVEY OF WESTERN AUSTRALIA
MAP SHOWING
DISTRIBUTION OF
ILMENITE - BEARING SAND
ON
TEMPORARY RESERVE 3160H
BOODANOO
YALGOO – MURCHISON GOLDFIELDS W.A.
SCALE
80 40 0 80 160 CHAINS
Compilation (uncontrolled) from aerial photographs and geology by L. E. de la Hunty. August, 1965.
REFERENCE
Main Road
Minor road
Track
Fence
Station boundary
Reserve boundary
Goldfield boundary
Homestead
Well or bore
Windpump
Photo centre
Run 7/5039
Geological boundary
Sample locality
No. 2620
Sand mainly aeolian
s
Ilmenite - bearing sand
is
Kopi dunes and banks
k
Clay and saline flats
c
Outwash, sometimes sandy
ow
Sand Plain
sp
Granite
gr
Gneiss
gn
Basic igneous rocks
b
To Mt. Magnet
To Sandstone
CHALLA
CHALLA STATION
WINDEMURRA STATION
MEELINE STATION
MEELINE
MURCHISON GOLDFIELD
YALGOO GOLDFIELD
ANKETELL STATION
BOODANOO
BOODANOO STATION
OAKDALE STATION
COOLAMANINU
Lucky Find Well
Boodanoo Well
Run 5/5013
Run 5/5007
Run 6/5060
Run 6/5055
Run 7/5035
Run 7/5041
Run 8/5060
Run 8/5054
Run 9/5129
Run 9/5131
Run 10/5153
Run 10/5149
Run 11/5230
Run 11/5238
Run 12/5053
Run 12/5058
Run 13/5075
Run 13/5070
No. 2628
No. 2627
No. 2617
No. 2616
No. 2615
No. 2625
No. 2624
No. 2626
No. 2620
No. 2621
No. 2622
No. 2623
No. 2619
No. 2618
No. 2612
No. 2613
No. 2614
LOCALITY MAP
Main road
Railway
SCALE
200 100 0 200 MILES
Carnarvon
Meekatharra
Mt. Magnet
Sandstone
Geraldton
TR 3160H
Leonora
Kalgoorlie
Perth
Bunbury
Esperance
Albany
24°
28°
32°
113°
117°
121°

PLATE 20

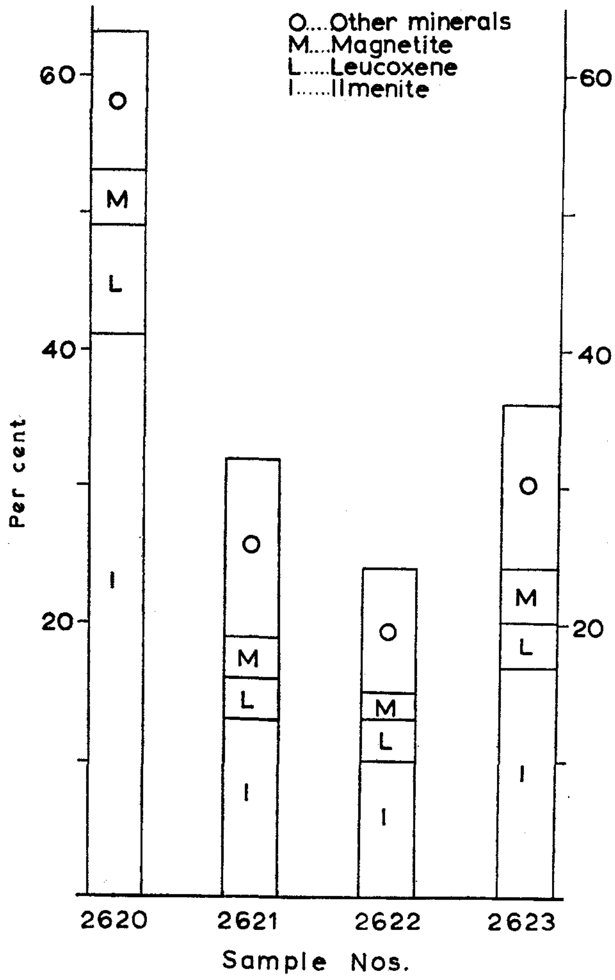


Fig. 22 Heavy mineral composition of some sand samples from 1.1/2 miles south of Boodanoo Trig.

RESOURCES

Although the sampling was of a broad reconnaissance nature, many 'eye assays' were made and the sampling is thought to be fairly representative of the material available. Two grades of ilmenite-bearing sand are indicated; those with an ilmenite content in the range 10 to 20 per cent, and those with 5 to 10 per cent of ilmenite. The remainder of the eolian sand shown on the plan (and perhaps some of the sandy outwash) has an ilmenite content in the range 0 to 5 per cent, with the possibility of local deposits of better material.

There may be 1,000,000 tons of the better grade of material (10 to 20 per cent ilmenite) and several million tons of the 5 to 10 per cent material.

CONCLUSIONS

1. This is the first inland occurrence of ilmenite reported in Western Australia, but it is possible that there are deposits in the vicinity of other salt lakes in the State, particularly where a lake and its drainage form a closed system.

2. The deposit has been formed by the resorting action of wind on lacustrine and eolian sand containing ilmenite.

3. The grains of ilmenite originally weathered from the Archaean basic igneous rocks and granite.

4. The principal heavy mineral in the deposit is ilmenite and there is a little leucoxene. There are no appreciable quantities of rutile, zircon or monazite.

5. None of the material can be classified as ilmenite ore under present conditions, because of its low ilmenite content and its geographical position. However, it increases the State's resources considerably and must be considered a significant low-grade deposit.

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MANGANESE NODULES IN MIDDLE PROTEROZOIC SHALE IN THE PILBARA GOLDFIELD, WESTERN AUSTRALIA

by L. E. de la Hunty

ABSTRACT

Lenticular manganese nodules occur within the Middle Proterozoic Noreena Shale in the Pilbara Goldfield. The shale is the source rock of several supergene manganese ore deposits in this region.

The nodules are all oriented with their principal axes normal to the planes of bedding in the shale, and are believed to have formed diagenetically by the concretionary deposition of manganese around nuclei of quartz or clay before compaction of the

sediment. Originally the nodules may have been composed of calcite which was subsequently replaced by manganese carried in water permeating the unconsolidated sediment. Alternatively, the nodules may have formed by the direct deposition of a manganese mineral from the contained water.

Most of the manganese in the host rock is considered to be primary but some may have been introduced during diagenesis. Some secondary mobilization of manganese has occurred both in the host shale and the nodules.

INTRODUCTION

Since the *Challenger* report (Murray and Renard, 1891) there have been many reports on manganese nodules. Some of the occurrences described are of manganese carbonate nodules, but most are of manganese nodules on, or near the surface of, modern pelagic deposits. Nodules have also been reported on the bottom of freshwater lakes and in exposed older sediments. The nodules have a great range in size and shape but are generally at least several centimetres in diameter and may weigh up to hundreds of pounds. Lateritic nodules are also common.

The nodules described in this report range in diameter from a few millimetres to a little more than 2 centimeteres, and have a consistent lenticular shape with a maximum thickness less than 0.5 cm. They have been recorded from four localities in only one area in Western Australia although the host rock has been examined in many parts of the North-West Division of the State.

The nodules were first seen by the writer in 1958 and reported on in the following year (de la Hunty, 1960). Employees on Noreena Downs Station knew of their existence at locality No. 2 and thought they were tektites. There may be more nodule localities in the area although many outcrops of the host rock are known to be barren.

The nodule localities shown on the accompanying plan are near the Davis River, about 50 miles by road east-southeast of Nullagine, in the Nullagine District of the Pilbara Goldfield. The road has been used for carting manganese ore but has now fallen into disrepair.

There are many small deposits of manganese oxide in the area, formed by supergene enrichment of manganiferous sediments. Openings were made in several of the deposits and the most productive has been that on M.C. 194L, immediately south of nodule locality 3. More than 30,000 tons of high-grade ore was mined from the deposit in 1958-60. Most of the deposits are too low-grade to be mined.

GENERAL GEOLOGY

The area is part of the Pilbara Manganese Province and falls within the Balfour Downs 1:250,000 Sheet (de la Hunty, 1963, 1964). The exposed rocks are Proterozoic and Cainozoic in age.

The Lower Proterozoic rocks in the area have been correlated with rocks of the Mt. Bruce Supergroup (MacLeod and de la Hunty, in press), and correlation of the Manganese Group with the Bangemall Group (Halligan and Daniels, 1964) is suggested here. These groups were previously considered to be Upper Proterozoic but are now designated Middle Proterozoic by Horwitz (1966) who correlates them with rocks older than Upper Proterozoic tillites.

The manganese nodules are associated with the chocolate-brown Noreena Shale which is one of the units of the Manganese Group.

Lower Proterozoic

The *Little De Grey Lava* is the oldest rock exposed in the area and crops out in the northwestern and southwestern parts. The lava is a green-grey amygdaloidal basalt, with pyroclastic bands, and is correlated with the Mt. Jope Volcanics. Outside the area, the lava overlies the Archaean basement, although it may be underlain locally by a post-Archaean conglomerate.

The *Lewin Shale* consists of shale, chert, jaspilite and thinly-bedded dolomite, and is characterised by oxidised pyrite balls in the shale outcrops.

The *Carawine Dolomite* is a blocky, grey and pink, crystalline, dolomitic limestone with chert bands. *Collenia* has been recorded in the lower part of the formation (de la Hunty, 1964).

Middle Proterozoic

The unconformity between the Lower Proterozoic and the Middle Proterozoic is readily identifiable where the *Pinjian Chert Breccia* is present. This breccia is the basal unit of the Middle Proterozoic and it is overlain by the Manganese Group. However, some of the chert breccia in the area caps a large plateau and is believed to be of Tertiary age. No attempt is made to differentiate the breccia of different ages. The breccia is composed of angular fragments of banded chert, cemented together with silica.

The *Manganese Group* is composed of shale, siltstone, sandstone and conglomerate, with some chert and limestone. These sedimentary rocks have a higher manganese content than the Lower Proterozoic rocks in the area and the Upper Proterozoic Bocrabee Sandstone. In adjacent areas, rocks of the Manganese Group are the source of numerous supergene deposits of manganese ore (de la Hunty, 1963, 1964). Only the Noreena Shale (chocolate shale to micaceous siltstone) was observed to contain manganese nodules. The sedimentary rocks of the Manganese Group are limited in areal extent and it is difficult to establish continuity between outcrops in many parts of the area. Also, the pebble and sand bands indicate a rather shallow water environment. This is distinctly different from the quiet, deep water environment generally considered essential for the deposition of manganese nodules.

The *Davis Dolerite* intrudes, and overlies, the Manganese Group. It is a fine to medium-grained rock and most of the exposures are sills that form treeless plateaux.

Cainozoic

The Tertiary rocks include laterite, colluvium and the Oakover Formation which consists of limestone and opaline silica. The undifferentiated Quaternary unit consists of sand and alluvium.

THE HOST ROCK

The Noreena Shale is the host rock for the manganese nodules. It has a manganese content, based on samples from many localities in the area, in the range 0.4 to 10 per cent Mn. Where shaly, the rock is hard and coherent and is dark chocolate-brown to red. Oxides of manganese are evident in the rock, in lenticular manganese nodules, (see Plates 28, 29), as joint fillings, along the bedding planes, and on the surface of outcrops. A white clay mineral is present in bedding planes and in the cores of nodules in some localities.

Where the rock is micaceous, the colour is usually paler and less manganese is observed. At nodule locality No. 4 the nodules were hard to see, because of a pale chocolate-coloured earthy skin, and also because the siltstone weathered into fragments that were similar to the nodules in shape, size and colour.

A specimen of chocolate-brown shale from 3 miles east of Mt. Divide, in the southern part of the area, was examined by the W.A. Government Chemical Laboratories and reported on as follows:

"A mudstone consisting of clay, fine quartz, a little limonite and hematite, and traces of an unidentified manganese mineral. Small concretions have been formed in several manganese-bearing layers. The concretions have a light coloured, friable centre consisting of quartz, clay, and limonite and a hard outer skin of manganese oxide. X-ray examination gave diffraction patterns too diffuse for definite identification of the manganese mineral. Manganese—0.65 per cent on dry basis."

ENVIRONMENT OF NODULE DEPOSITION

Many studies of deep sea floor environment have shown that manganese nodules are produced in pelagic sediments. Most of the work has been carried out in the Pacific area and Pachadzhanov and others (1963) have studied nodules from the Indian Ocean.

Shipek (1960) says ". . . the rate of accumulation of pelagic sediments is closely related to the chemical formation of manganese nodules to account for the existence of widely distributed and exposed quantities of such free minerals on the sea floor. The chemical and physical processes which appear to be responsible for their (the nodules) formation are active at the interfaces of both deep clays and oozes."

Mero (1960b) wrote that the nodules are formed from charged particles which collected together, taking in cobalt, nickel, copper, radioactive material, etc. Dietz (1965) suggested that the MnO_2 is widely precipitated as colloidal particles, rather than ions, and that the colloidal manganese is a scavenger for nickel and cobalt.

In either case, the nodules form at the sediment-water interface and, if the rate of sedimentation exceeds the rate of accretion of manganese oxides, the formation of the nodule ceases. Mero recorded nodules several centimetres across and also many weighing more than 100 lbs. Olaussen and Uusitalo (1964) suggested that seismic vibrations may have contributed to the formation of the nodules by causing the nodules to remain at the sediment-water interface, despite the fact that the recorded rate of growth of the nodules was less than 1 mm per 1,000 years, and the reported rate of sedimentation for red clays and oozes is 1 mm to several centimetres per 1,000 years.

Where the process is interrupted, small pellets and nodules of manganese oxides should form in the bedding planes of a shale, as at Noreena. However, it is unlikely that the nodules at Noreena are primary as there is no warping of the bedding of the shale around the nodule. Relic bedding, parallel to the bedding of the shale, is apparent within the nodules (see Plate 31, E & F). Furthermore, the sediments of the Manganese Group are characteristic of disturbed conditions of deposition and these nodules were probably deposited in rather shallow water, under variable, but mainly quiet, conditions.

The granzon ore (Park, 1942) of Cuba consists of nodules and pellets of manganese oxide in soil and subsoil near outcrops of other kinds of manganese ore. The pellets are usually less than half an inch in diameter and are made up of concentric layers of manganese oxide. The granzon ore has formed during lateritic weathering of a maganiferous deposit and contains iron oxide impurities, often grading into pellets of iron oxide. This granzon is similar to a deposit of pisoliths and pebbles in soil, about half a mile south of the main manganese deposit at Balfour Downs, 32 miles south of nodule locality No. 4, (de la Hunty, 1963, p. 88) but is distinctly different from the Noreena nodules and pellets.

DESCRIPTION OF THE NODULES

Physical Properties

Unlike other nodules reported, these are all of comparable shape and size. They are circular in plan and lenticular in section, resembling tektites (see Plate 30). The nodules are probably flattened concretionary structures, which were originally spherical but were deformed on compaction of the host sediment.

Since the nodules are shaped like biconvex lenses, optical terminology is useful for their description. There is only one axis of symmetry, called the "principal axis", and the plane of symmetry normal to this axis (through the optical centre of a lens) is called the "principal plane".

It will be observed from the photographs that the nodules are not exactly symmetrical about the principal plane, nor are they exactly biconvex. Many of the nodules are attenuated at the principal plane, and the resulting halo increases the diameter of the nodule by as much as 30 per cent. In some cases adjacent haloes coalesce and the resulting nodule is shaped like a dumbell in section.

The nodules are less than 3 cm across and generally less than 1 cm thick. The largest measured diameter was 2.8 cm and the maximum thickness observed was 1.1 cm. A collection was made of the larger nodules from locality No. 2 and these had diameters in the range 1.7 to 2.8 cm, with a rather constant thickness of 0.7 cm. The average weight of 10 of these nodules was 4.6 grams.

Most of the nodules shed in all four localities were smaller, being 0.8 to 1.3 cm across and about 0.5 cm thick, or less. There were also many small nodules as in Plate 29.

In the host rock, the nodules are always disposed with the principal plane parallel with the bedding of the shale. Also concentric rings are visible on many of the nodules, both top and bottom (see Plate 30A). These are the impressions of the bedding of the shale and prove that these nodules all had the same attitude in the rock before weathering out.

The nodules are black inside but the surface is usually chocolate-coloured because of a film of clay from the chocolate shale. The nodule surface is rough but the irregularities are small.

Mineralogy

Many investigators have reported on the amount of manganese in deep sea manganese nodules. The nodules usually contain less than 30 per cent manganese but Mero (1960b) recorded a maximum value of 50 per cent Mn. The manganese is always present in the oxide form.

Some nodules from locality No. 2 contain 43 per cent Mn and the manganese mineral has been identified as braunite. Impurities are iron oxide and a little quartz. The nodules are hard and brittle. They are black, with a chocolate-coloured clay coating, and have a black streak. Concentric growth rings are discernible about a central nucleus (see Plate 31 B, C). However, concentric structures are not apparent in the sections cut through the principal axis (see Plate 31 E, F). One of the most striking features of the sections in Plate 31 E, F is the straight, parallel banding, which is without doubt the original bedding of the replaced shale.

The nuclei have been identified in thin-section as chert and clay, for the most part. The chert is angular and fractured, with manganese oxide along the cracks, and the clay is also partly replaced by manganese oxide. Replacement of the clay nucleus is evident in Plate 31 E but there has been no infilling of the cracks in the nucleus by manganese oxide. The darker bands and patches in Plate 31 E, F are concentrations of manganese oxide. Plate 29 shows several small nodules which have been breached during erosion. These have comparatively large cores which were probably composed of white clay. Not all of the nodules have a well-formed nucleus (Plate 31D) and some have more than one nucleus (Plate 31F).

ORIGIN

There is little doubt that the nodules were formed by concretionary deposition of some mineral around a nucleus of quartz or clay in the shale. This mineral may have been an oxide of manganese or replacement by manganese may have occurred after the formation of the nodule. Discussion on the origin of the manganese nodules may, therefore, be conveniently divided into two sections:

1. the formation of the nodules,
2. the introduction of the manganese.

Formation of the nodules

Nodules may be primary, as in the case of the manganese nodules in modern pelagic deposits; or diagenetic, formed subsequent to the deposition of the sediment but prior to lithification; or secondary, having formed after the rock was exposed to weathering processes.

Twenhofel (1939) states that the quantity of water contained in a fine-grained sediment is usually in excess of 50 per cent by volume; so that a shale would be reduced to less than half its original thickness when lithified. The principal axis of any nodule from the Noreena Shale is less than half the length of a diameter in the plane of symmetry, so it is likely that the nodules were originally spherical but were flattened on compaction of the sediment. There are several cracks normal to the principal plane in Plate 31E, and such fracturing is consistent with vertical compression of the nodule after formation. The shape and the fracturing of the nodules indicate that the nodules were formed before compaction and lithification of the sediment; so they are primary or diagenetic structures.

If the nodules were primary, there should be some warping of the enclosing sediment, due to compaction, in the vicinity of the nodules. No such warping was seen. Furthermore, the relic shale bedding within the nodules in Plate 31E is evidence that the concretions were formed subsequent to the deposition of the shale. They must, therefore, be diagenetic structures.

Introduction of the manganese

Braunite has been determined in the nodules and it is very likely that other oxides of manganese exist in both the nodules and the host rock. Because of the extreme mobility of manganese oxides under weathering conditions, much of the original manganese contained in the rock may have been redistributed by secondary processes, so any considerations of the time of deposition of the manganese in both the host rock and the nodules must allow for secondary processes.

If the nodules were primary, regardless of mineral content at the time of deposition, then there are nine possible combinations of ways in which manganese could have been introduced into the rock and the nodules. These are the possible combinations of primary, diagenetic and secondary (with secondary mobilization superimposed), as shown in the table.

POSSIBLE EMPLACEMENT OF THE MANGANESE

Case No.	In Noreena Shale	In Nodules
1	Primary	Primary
2	Primary	Diagenetic
3	Primary	Secondary
4	Diagenetic	Primary
5	Diagenetic	Diagenetic
6	Diagenetic	Secondary
7	Secondary	Primary
8	Secondary	Diagenetic
9	Secondary	Secondary

Since it has already been established above, that the nodules are of diagenetic origin, cases 1, 4 and 7 are untenable. The host rock has a background content of about 0.5 per cent Mn, and is a source rock for supergene deposits, so its manganese is either primary or diagenetic. This rules out case 7 again, also cases 8 and 9, leaving 4 cases and possible combinations of these.

Had the nodules been primary, it would have been expected that the manganese in them would be primary, regardless of whether it was deposited as a carbonate, oxide, or hydrated oxide; but, since the nodules are diagenetic, they may have been composed originally of calcium carbonate which was later replaced by manganese oxides. Some of the manganese in the host rock could be diagenetic, but the most likely time of deposition is during sedimentation, so cases 2 and 3 should be considered.

If the manganese was introduced into the nodule during diagenesis, as in case 2, it possibly replaced calcite in the nodule. According to Savage (1936), some manganese may be deposited as a carbonate when a bicarbonate solution of manganese flows over a limestone bed. However there was little or no calcium carbonate in the Noreena Shale, except possibly in the nodules.

The dense black mineral filling cracks in the nodules in Plate 31E, F, is a secondary manganese oxide and is obviously later than the braunite (grey) in which the cracks occur. Since these cracks were considered to prove that the nodule was diagenetic, it must also be assumed that the braunite was introduced into the nodule before compaction and that the manganese content in the nodules is diagenetic for the most part.

CONCLUSIONS

The manganese nodules described here are different from those in modern pelagic deposits, since they were formed during diagenesis of a fine-grained sediment, instead of having been deposited as primary features of the sediment.

Most of the manganese in the host rock is considered primary but the manganese in the nodules is diagenetic, with some secondary replacement. The nodules were formed during diagenesis but they may have been of calcite, or similar material, which was replaced by manganese minerals before compaction took place.

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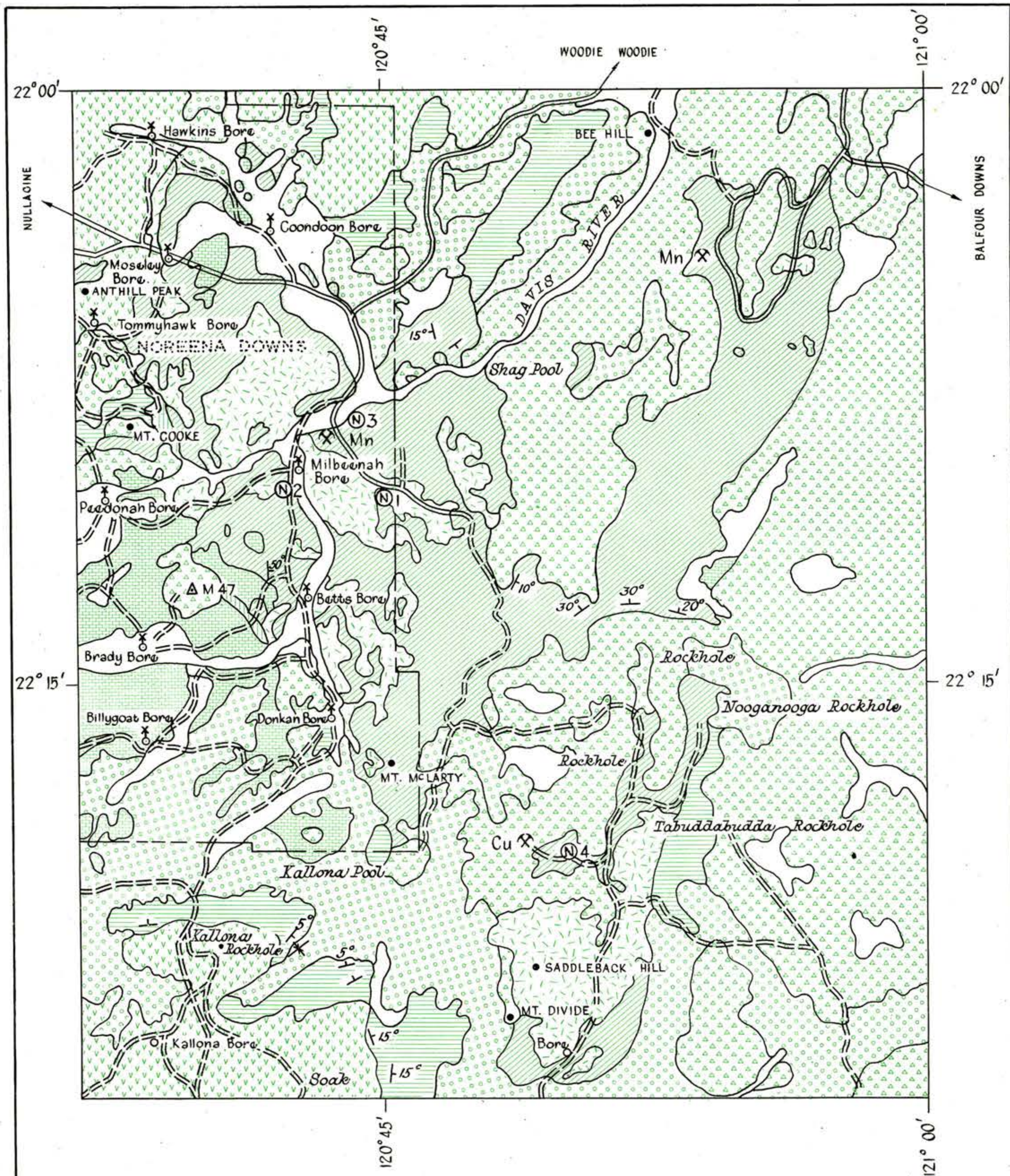


REFERENCE

QUATERNARY		Undifferentiated
TERTIARY		Oakover Formation : limestone & opaline silica
		Laterite & Colluvium
MIDDLE PROTEROZOIC		Davis Dolerite
		Manganese Group
		Pinjian Chert Breccia :- (some breccia may be Tertiary)
LOWER PROTEROZOIC		Carawine Dolomite
		Lewin Shale
		Little DeGrey Lava

SYMBOLS

Geological boundary	
Road	
Track	
Beacon	Δ M47
Bore with windpump	Betts Bore
Manganese mine	Mn
Copper mine	Cu
Manganese nodule locality	(N) 2

SCALE OF MILES

4 0 4 8

GEOLOGICAL SURVEY OF WESTERN AUSTRALIA

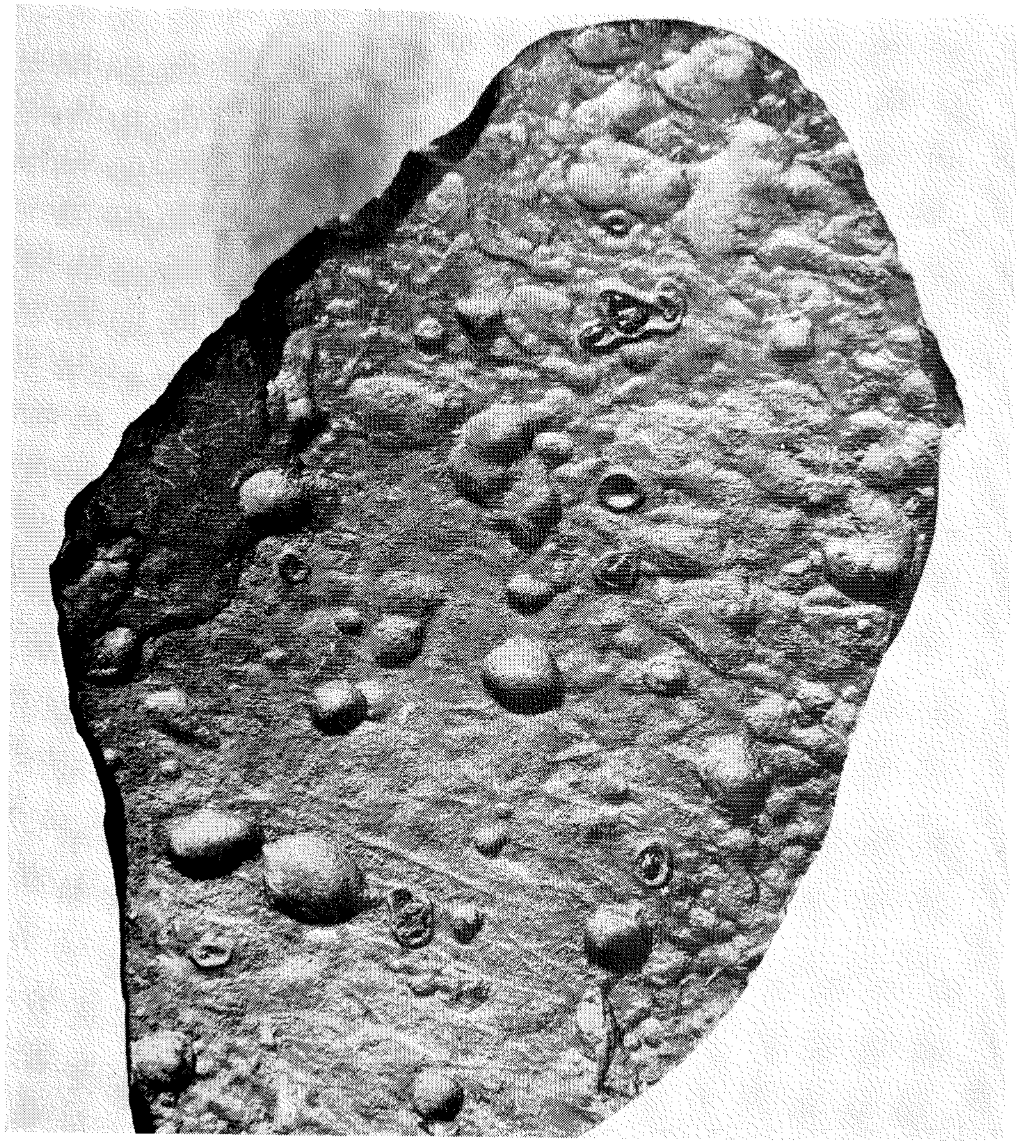
GEOLOGICAL MAP OF PORTION OF PILBARA GOLDFIELD SHOWING LOCALITIES OF MANGANESE NODULES

L. de la Hunty 1965

8567

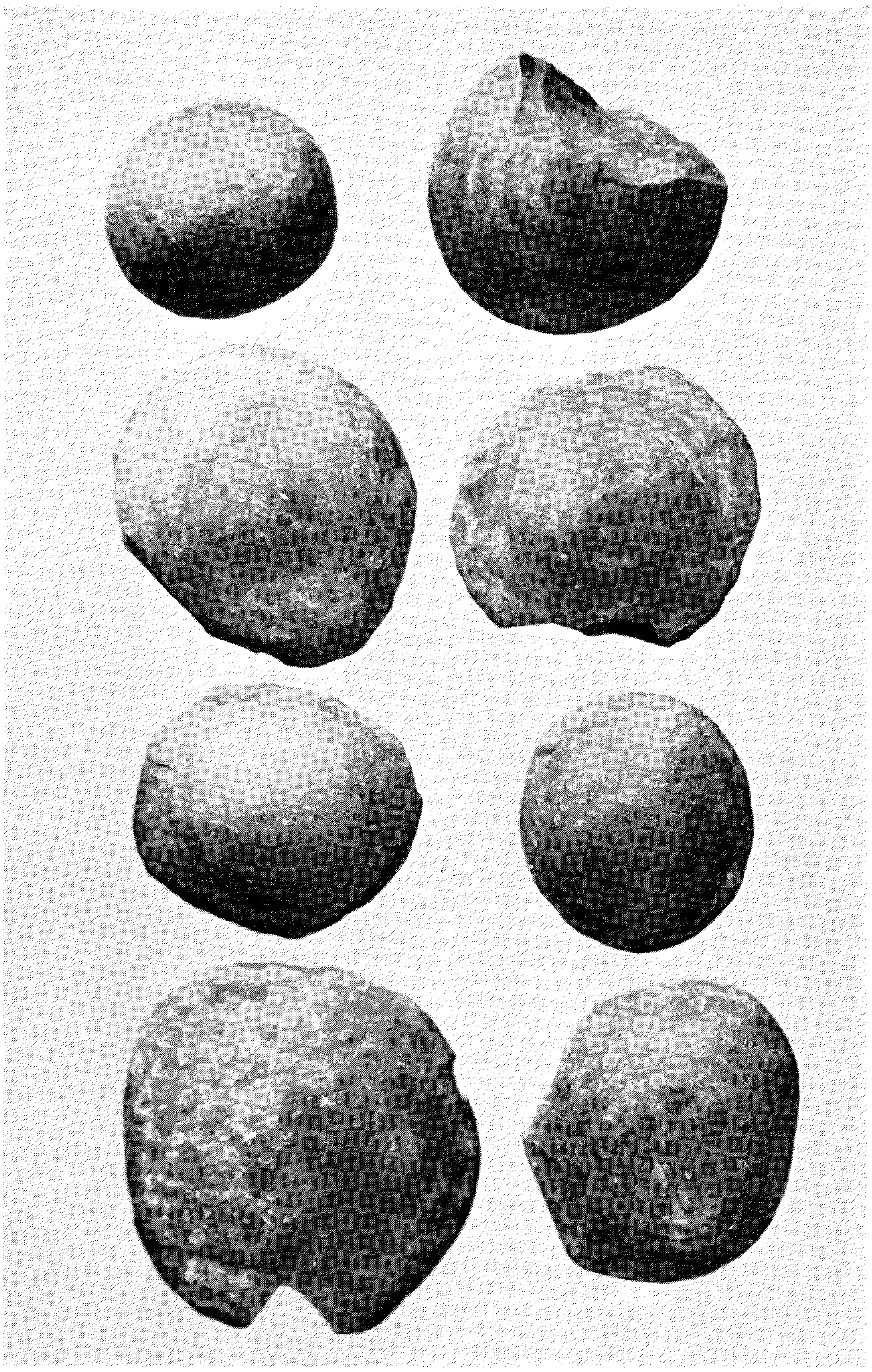
Section through chocolate shale, showing shape and distribution of manganese nodules. Scale x 2.

PLATE 28



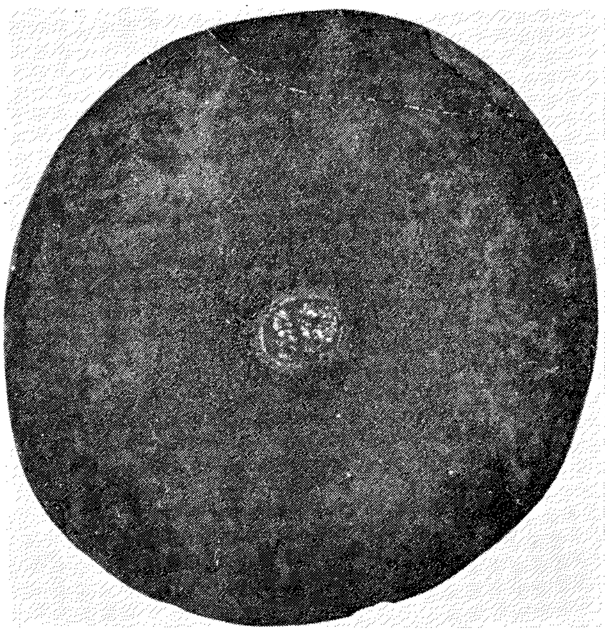
A—Surface of chocolate shale, showing manganese nodules and casts of nodules. Scale, natural size.

B—Enlargement of portion of rock in Fig. 2. Scale x 3 (approx.).

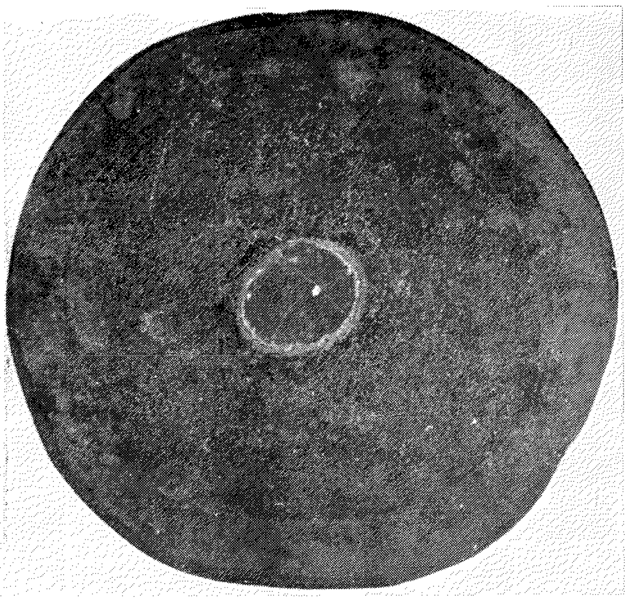


A—Plan view of larger manganese nodules, showing haloes and bedding impression. Scale x 2.

B—Side view of manganese nodules. Scale x 2.



A



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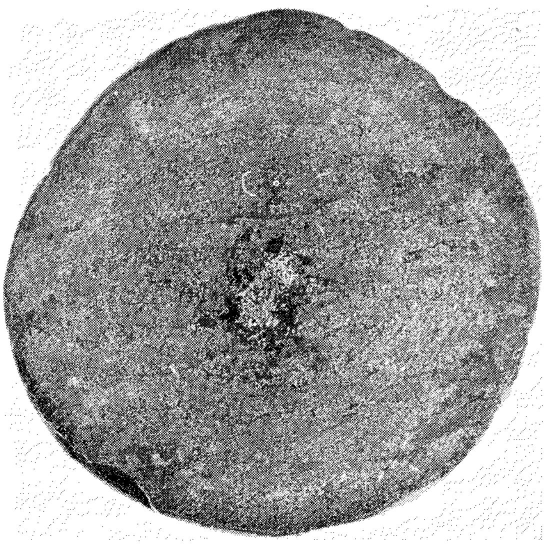
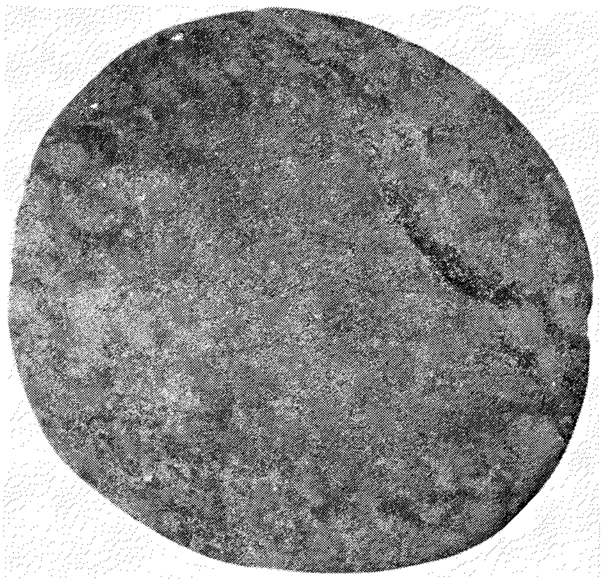
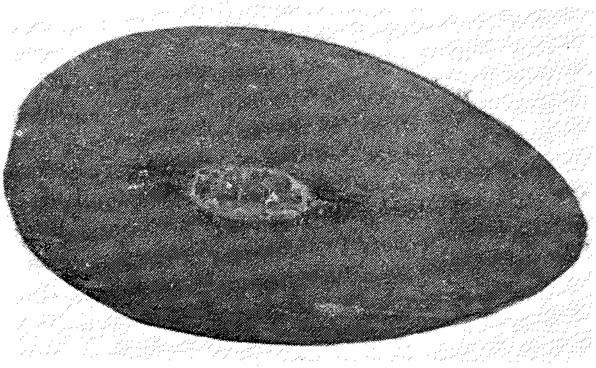


C



D

Polished sections of 4 manganese nodules cut through principal plane. Scale x 4.



E

F

Polished sections of 2 manganese nodules cut through principal axis. Scale x 4.

BAUXITE DEPOSITS OF THE NORTH KIMBERLEY REGION, WESTERN AUSTRALIA

by John Sofoulis

ABSTRACT

Extensive bauxite deposits were discovered in the northern part of the Kimberley Division in May, 1965, by a geologist of the United States Metals Refining Company. The bauxite occurs as Tertiary or pre-Tertiary plateau remnants overlying weathered basic rocks of Proterozoic age. Preliminary investigations indicate that the deposits are extensive and of high grade. A drilling programme to evaluate the bauxite is in progress.

INTRODUCTION

Interest in the possible occurrence of bauxite in the Kimberley region was stimulated by the discovery of bauxite in other tropical areas of Australia, notably at Weipa and Gove. In 1958, Reynolds Pacific Mines Pty. Ltd. commenced investigations in some of the north coastal areas of Western Australia, and examined and sampled the laterite plateau of the Cape Bougainville Peninsula. Results in this area were disappointing. The laterite had a low alumina content (20 per cent to 40 per cent total Al_2O_3) and the company relinquished its Temporary Reserves (T.R. 1606H and 1702H).

In March, 1965, United States Metals Refining Co., a subsidiary of American Metals Climax Inc., was granted a Temporary Reserve (late T.R. 3231H) to investigate the laterite developed over basic rocks in the area south of Admirality Gulf, and in the Couchman Range—Foster Range area. Extensive laterite cappings in these areas had been recognized by photogeological examination.

The company undertook field investigations of these areas in May and June, 1965 with a small party under the supervision of Mr. D. K. Malcolm. This survey confirmed the presence of high-grade bauxite. The original Temporary Reserve was amended and reduced to four smaller areas which cover the principal bauxite deposits (T.R.'s 3500H, 3501H, 3502H and 3503H).

The bauxite areas were inspected by the writer in June and July, 1965 during the course of a combined Commonwealth and State geological survey of the Kimberley Plateau. A regional geological map on a scale of 1:500,000 accompanies this report (Plate 32). This map is based on photogeological compilations prepared by the Commonwealth Bureau of Mineral Resources photogeological section, supplemented with helicopter traverses, and covers parts of the Prince Regent, Ashton, Montague Sound, Drysdale and Londonderry 1:250,000 Sheets.

At the time of writing (November, 1965) the company was engaged in a drilling programme to gain a greater appreciation of the reserves and grade of bauxite available.

LOCATION AND ACCESS

The bauxite deposits are situated in an uninhabited part of the Kimberley Division north of latitude 16° S. and between longitude 125° 30′ E. and 126° 30′ E.

Access to the Couchman Range and Foster Range is from the south by a bush track from Gibb River Station, which is 260 miles east-northeast of Derby. The track has been extended for company investigations to cross the King Edward River and thence westward to some areas with high-grade bauxite that lie south of Admiralty Gulf (see Plate 32).

A road construction team of the Main Roads Department is forming and grading a new earth road to connect Gibb River Station to the Kalumburu Mission on the north coast via the Drysdale River crossing. All roads are impassable during the wet season (November to March).

The nearest airstrips suitable for D.C.3 aircraft are those at the Kalumburu Mission and Gibb River Station. With a minimum amount of clearing some of the upland swamps near the bauxite deposits could be used during the dry season as landing strips for light aircraft. Natural harbours are abundant along the northern coast most of which is accessible by vessels of shallow draught.

GENERAL GEOLOGY

The general geology and geomorphology of the region have been described by Harms (1959) and by Speck and others (1960). The area forms part of what is commonly known as the Kimberley Plateau which consists mainly of well dissected Proterozoic sediments and volcanic rocks, locally interspersed with sandy and lateritic tablelands.

Proterozoic rocks

The principal rock exposures are either of King Leopold Sandstone or the overlying Carson Volcanics. These two formations are briefly described below. They comprise the lowermost units of the Kimberley Group as defined by Dow and others (1964). Higher units of the Kimberley Group, viz. Warton Sandstone, Elgee Siltstone and Pentecost Sandstone, are locally exposed in a monoclinal flexure in the extreme southeastern part of the area. Warton Sandstone also overlies Carson Volcanics in some offshore islands. Sills of Hart Dolerite (Dow and others 1964) are restricted to the King Leopold Sandstone within the Sheet area, but elsewhere in the region the dolerite is known to intrude all units of the Kimberley Group.

The *King Leopold Sandstone* consists almost entirely of white, medium-grained, thin and thick-bedded quartz sandstone, which ranges from poorly cemented friable varieties to silica-cemented forms. The sandstone is characterized throughout this region by strong cross-bedding. Basal beds of the formation are not exposed in the mapped area.

The *Carson Volcanics* conformably overlies the King Leopold Sandstone. The formation consists of dark green to black rocks which are mainly altered and readily weathered tholeiitic basalts including highly amygdaloidal types. It occupies broad synclines but in the less disturbed areas forms flat-lying sheets. The Carson Volcanics is approximately 2,000 feet thick.

Tertiary laterites and associated soils

Lateritic duricrust overlain by residual sandy and lateritic soils form part of an old Tertiary or pre-Tertiary land surface. The duricrust is developed mainly over the Carson Volcanics and is preserved in interfluve areas as dissected tablelands bounded by indented escarpments up to 300 feet high. The plateau surface, which is about 1,000 feet above sea level in the hinterland regions, shows a gradual fall northwards to the coast and is being actively eroded at sea level in some coastal areas and in offshore islands.

Where developed above basic rocks, the laterite is usually between 10 and 30 feet thick. Sandstones have been less susceptible to laterization and these seldom show duricrusts greater than 2 feet thick. Elsewhere the lateritic effects over sandstones are represented by a slight surface ferrugination or by the development of residual sands and skeletal lateritic soils.

THE BAUXITE DEPOSITS

The laterite includes both ferruginous and aluminous types. Bauxite is mainly confined to areas underlain by basic rocks and shows thicker developments and higher grades over synclinal areas where the Carson Volcanics is best preserved.

Description of bauxite ores

Bauxite deposits of the area include vari-coloured buff ores that range from hard, massive, blocky varieties to cellular, and partly cemented forms, as well as loosely compacted and friable pisolitic types. In general, the paler colour of the ore indicates a higher alumina content, although it is probable that many of the coloured varieties would also be of ore grade.

Some light-coloured bauxites appear as cellular or massive porcelanous ores and contain few, if any, pisoliths. Other light-coloured ores may be strongly pisolitic with spherical or ovoid pisoliths that range in size from a few millimetres to several centimetres across. Many of the larger pisoliths are compounded from a number of smaller ones.

Brecciation of the more massive bauxite and recementation by bauxitic material is common. Bauxitic pisoliths commonly occur in a ferruginous groundmass whereas the occurrence of ferruginous pisoliths in a bauxite groundmass is rare. The pisoliths usually show a concentric layering with ferruginous inner cores commonly enveloped by aluminous outer layers. This suggests that the bauxitic material is either a later development or a replacement of the ferruginous form.

In section, the bauxite locally shows a crude horizontal stratification which may be emphasised by hard or soft duricrust, cavernous, cellular or brecciated layers, as well as by oxide of iron or alumina indurations and colour variation. Dark-brown to black pisolitic ironstone locally forms a surface layer up to 2 feet thick above the lateritic profile. It is not known whether this layer is part of the same weathering profile, or belongs to a later period of iron precipitation.

Extent and thickness of bauxite deposits

The distribution of the laterite, as determined from helicopter traverses and photo geological interpretation is shown on Plate 32. Not all this laterite is bauxitic because oxides of iron predominate over alumina in some areas. From the reconnaissance survey it would appear that the higher grade bauxite deposits occur mainly within T.R. 3500H and are estimated to cover an area of at least 40 square miles.

The total thickness of the laterite profile, as noted in natural sections, is usually about 50 feet. The bauxitic zone, forming the upper part of the profile, ranges from a few feet to 30 feet or more in thickness. The average thickness of available ore is estimated to be 12 feet.

The passage from the duricrust to the underlying volcanic rocks is irregular and transitional and is determined only by an increase in the content of oxidized volcanic rock and a decrease in content of laterized material. The transitional zone is seldom more than 20 feet thick and is underlain by relatively fresh volcanic rocks.

Grade of bauxite

Preliminary results show the bauxite to consist of mixtures of trihydrate (gibbsite) and monohydrate (boehmite) oxides of aluminium, together with iron oxides, minor amounts of combined and fixed silica, and titania.

The analyses of four surface samples of light-coloured porcelanous laterite, collected during the survey from the positions shown within T.R. 3500H, are given in Table 1.

Table 1

PARTIAL ANALYSES OF FOUR BAUXITE SAMPLES FROM T.R. 3500H

Analyses by Mineral Division, Government Chemical Laboratories

G.S.W.A. Marks	M.S. 10–71–2	M.S. 11–09–1	M.S. 14A–06–2	M.S. 12–22–1
Lab. No. (1965)	11719	11720	11721	11722
	Per cent on dry basis			
Available Al_2O_3	42·2	53·3	48·7	57·7
Total Al_2O_3	47·5	58·8	61·9	59·4
Reactive SiO_2	1·00	1·60	1·31	1·20
Total SiO_2	1·24	1·64	1·38	1·24
Fe_2O_3	15·6	4·59	4·15	3·57
TiO_2....	10·2	4·99	4·09	4·32

Extensive areas of similar light-coloured porcelanous laterite noted in the plateau areas of the reserve thus comprise a huge potential source of bauxite ore. It is also likely that with selective mining or simple beneficiation (e.g. washing, screening) some of the lower grade laterite would also yield a substantial tonnage of ore at grades well in excess of 40 per cent Al_2O_3.

The deposits will require evaluation before any reliable estimate of reserves can be given.

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STAR OF MANGAROON GOLD MINE, ASHBURTON GOLDFIELD

by J. L. Daniels

LOCATION

The Star of Mangaroon gold mine is located at approximately 23° 52′ S. latitude and 115° 44′ E. longitude, 8 miles northeast of Mangaroon Homestead in the southwestern corner of the Edmund 4-mile Sheet area. It is approached from Mangaroon Homestead by a reasonably good earth road.

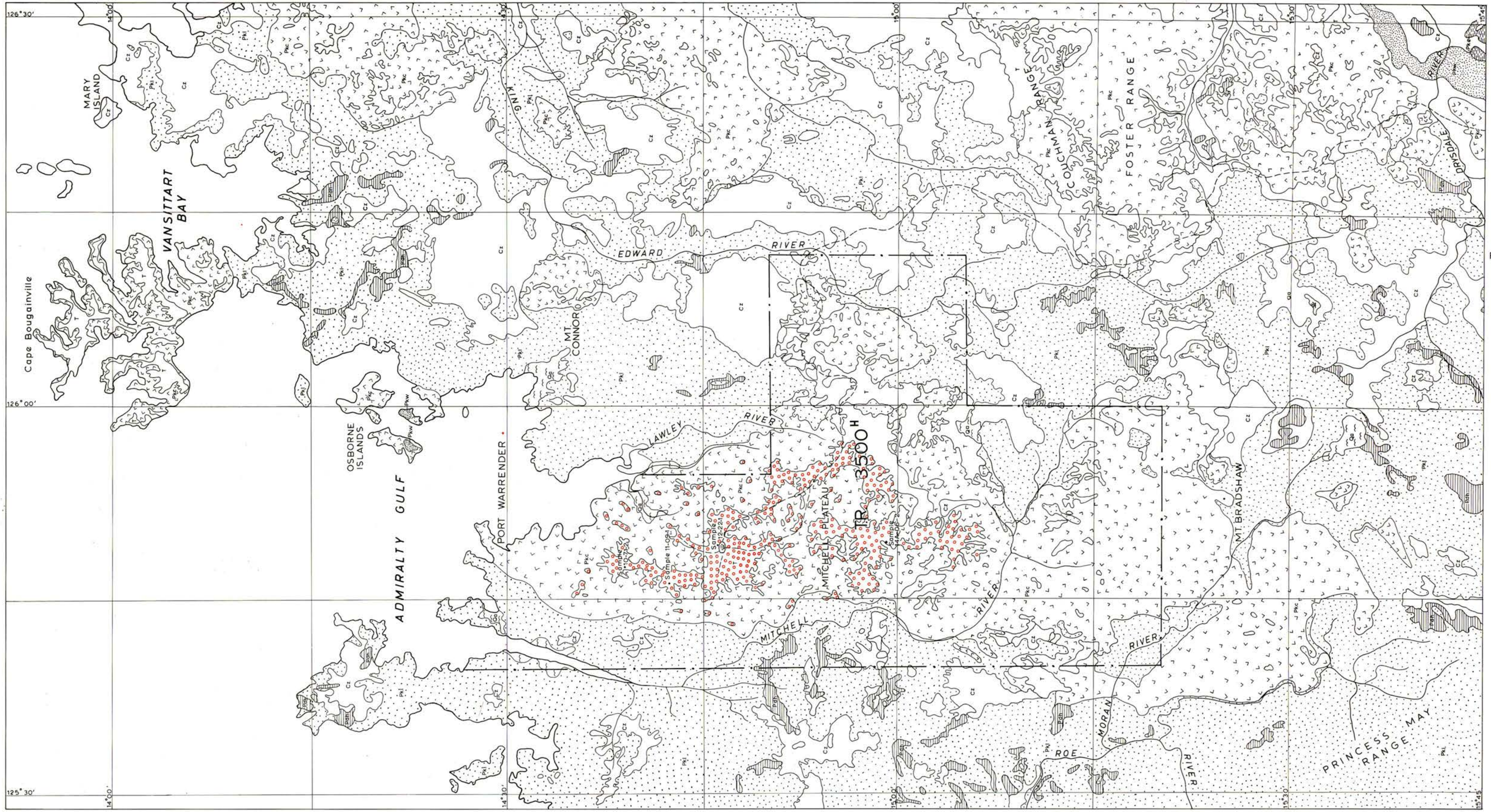
GEOLOGICAL SETTING

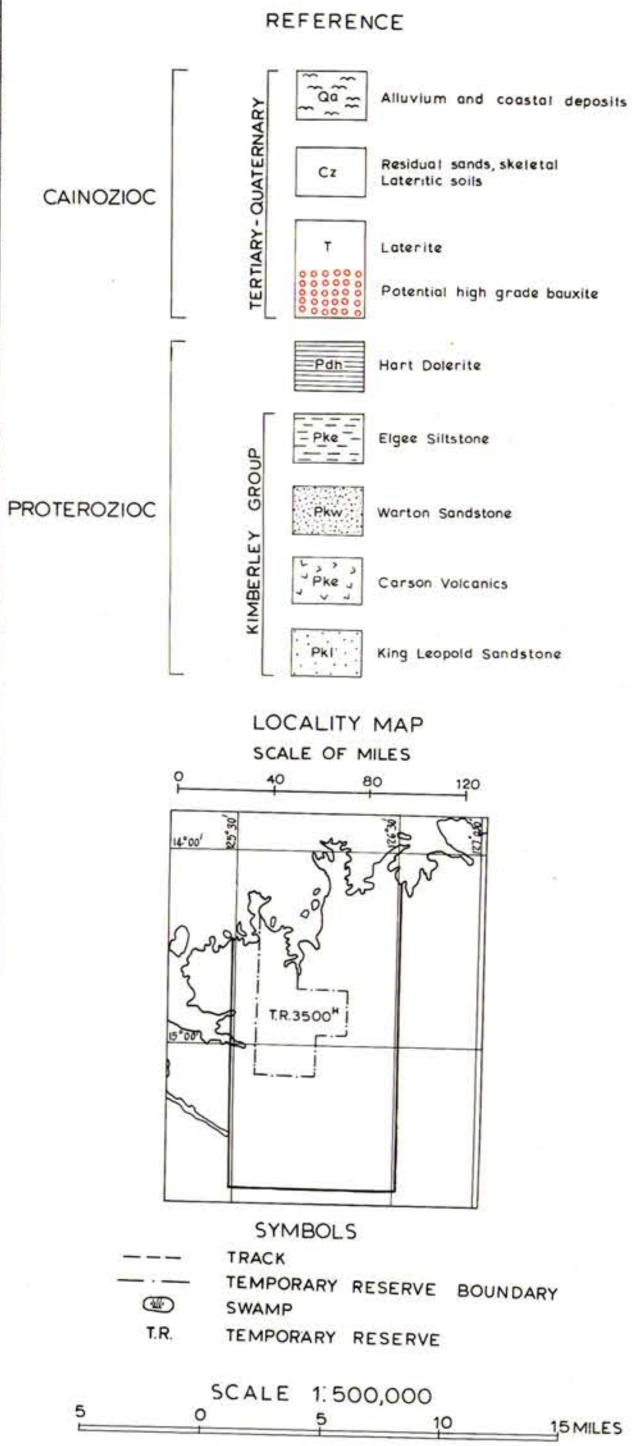
The mine is situated in an area of high-grade gneisses and migmatites. About 4 miles to the northeast these rocks are overlain unconformably by folded, unmetamorphosed sediments of the Proterozoic Bangemall Group. All are intruded by numerous, fresh dolerite dykes.

No age determinations are available for rocks in the vicinity of the mine. Probably the gneisses are the southern continuation of the Wyloo Group sediments, which, in the Ashburton Valley are seen to be regionally metamorphosed and intruded by granite during the Ophthalmian Fold Period (Halligan and Daniels, 1964; Daniels, 1965). A maximum indicated age of 1,850 million years is given by Leggo and others (1965) for a tuffaceous siltstone near the base of the Ashburton Formation, the youngest recognised formation in the Wyloo Group. The age of the metamorphism is probably only a little older than the age of the Boolaloo Granodiorite given as 1,720 million years by Leggo and others (1965).

Approximately 100 yards north of the mine, the gneisses and migmatites are well exposed in a small hill. They are complexly folded with minor fold axes plunging at 64° in a direction 302°. Almost vertical axial plane cleavages are common. Northwest from this hill the structural pattern is fairly simple and similar to that of the hill itself. At the mine and immediately to the east and south no consistent structural pattern could be found. As the orientation of the structural elements appears to change abruptly it is thought that faulting rather than subjection to a further folding is the cause of the structural variation.

In thin-section, one well-banded sample from the small hill north of the mine, consists of layers of quartz and biotite alternating with layers of quartz, cordierite, biotite and muscovite with accessory garnet, feldspar and zircon. The biotite in both types of layers occurs as short, medium-brown laths exhibiting moderate pleochroism. Small opaque inclusions are common and most frequently concentrated at the lath terminations. Intensely pleochroic haloes exist around small included zircons. The cordierite occurs as elongated, irregularly shaped grains carrying abundant rounded inclusions of quartz and laths of muscovite and biotite. Secondary alteration of the cordierite to a fine-grained aggregate of sericitic and chloritic material is apparent along irregular cracks. More rarely the alteration affects the whole grain. Very pale pink garnet is confined to small grains pseudomorphic after small portions of the cordierite crystals.





BAUXITE IN THE NORTH KIMBERLEY REGION WESTERN AUSTRALIA

GEOLOGY BASED ON B.M.R. PHOTOGEOLOGICAL INTERPRETATION, WITH HELICOPTER TRAVERSES

9024

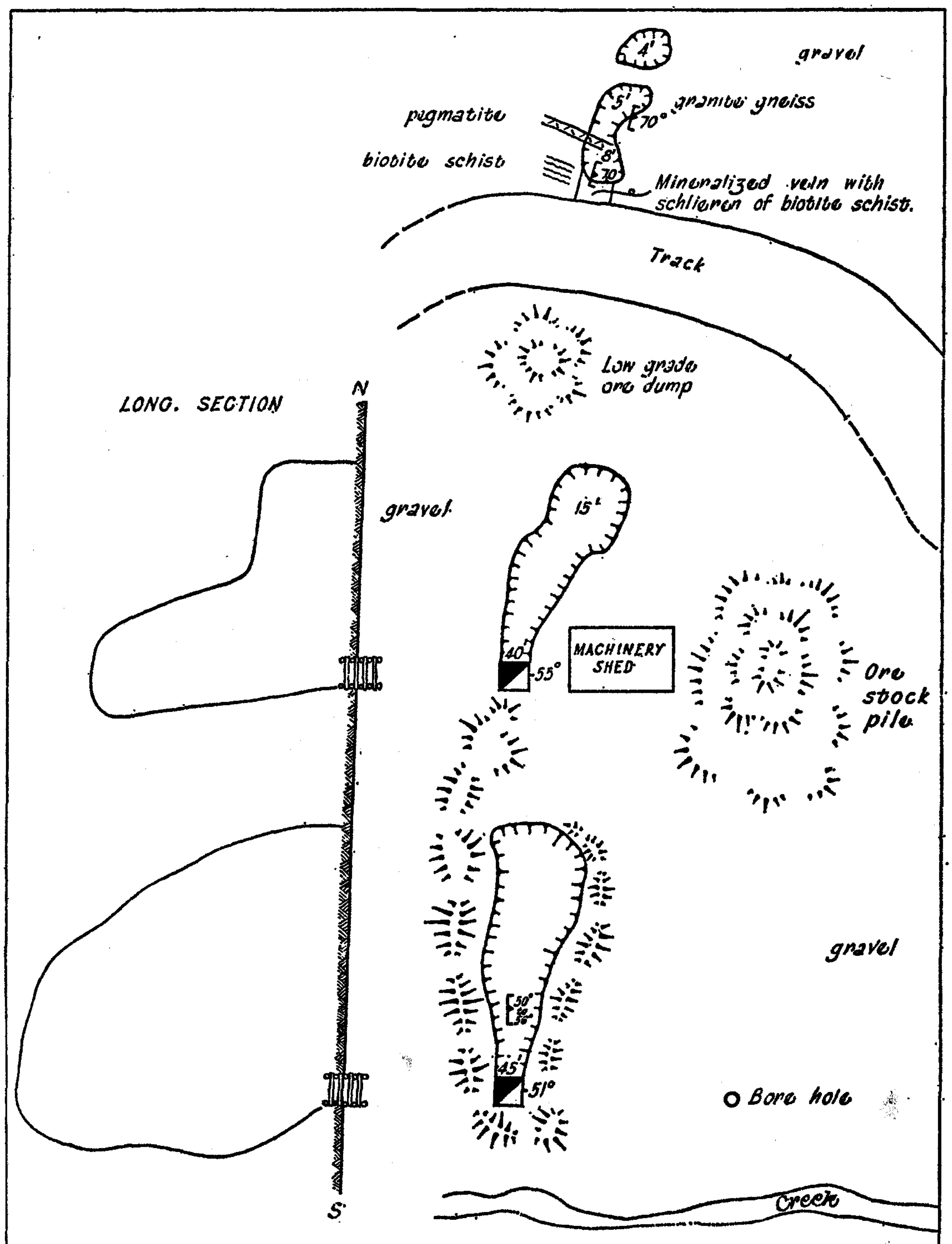


FIGURE 23
GEOLOGICAL SURVEY OF WESTERN AUSTRALIA
SKETCH OF STAR OF MANGAROON
GOLD MINE WORKINGS
J.L.Daniels 1965

SCALE OF FEET
10 0 10 20

Dip of mineralized vein 70

Shaft, inclined

Another sample from the same locality consists of medium to coarse-grained quartz, microcline microperthite, cordierite, biotite, muscovite, sillimanite and accessory tourmaline, plagioclase and zircon. It appears to be a granitic rock contaminated by a large amount of metamorphosed shaly material.

ORE BODY

The gold-bearing vein has a northerly strike and an average plunge of 51° to the east. The plunge rolls somewhat and dips between 24° and 70° have been measured. Occasional slickensides on the hanging wall plunge at 61° in a direction of 115°. A sketch plan of the workings is given in Figure 23.

Exposures next to the workings are poor, but the wall rock in the mine shows the country rock in the immediate vicinity to be composed mostly of granitic gneiss with schlieren of biotite schist and rare pegmatite veins.

The ore zone averages 50 to 56 inches in width and at the bottom of the southern slope consists of three main quartz-rich veins of 9, 10 and 20 inches width, separated by bands of biotite schist and biotite granite gneiss.

When fresh the vein rock is pale blue-grey, but becomes pale brown in the upper oxidised part of the mine. It consists largely of a granular aggregate of quartz with muscovite and minor plagioclase. Free gold as small (1mm) flakes are occasionally noticed. In the vein rock, Government Chemical Laboratories have identified the following minerals, all of which are present in small quantities: deep-green spinel, rutile, chlorite, pyrite, pyrrhotite, arsenopyrite, gold, garnet, tourmaline, and a mineral having similar properties to sapphirine but biaxial positive.

Samples of the fresh vein rock taken from the ore dump assayed 6 oz, 18 dwt, 19 grains gold per long ton, while the granitic gneiss between the veins assayed 1 oz, 16 dwt, 13 grains per long ton. Small, thin, hematite-rich veins cutting the ore zone assayed 2 oz, 6 dwt, 7 grains per long ton. The footwall rock from immediately north of the machine shed assayed 6 dwt, 14 grains per long ton.

Nothing is known about reserves in the mine as no exploratory drilling has yet been undertaken.

PRODUCTION

To date all ore has been carted to Meekatharra, and treated at the Meekatharra State Battery.

Period		Gold from dollied samples Fine oz.	Ore treated Long tons	Gold therefrom Fine oz.	Total Gold Fine oz.	Silver Fine oz.
1960/61	....	....	97·00	376·12	376·12	....
1961/64	....	3·50	460·75	1,027·19	1,030·69	32·67

Note: 155 tons crushed at Meekatharra State Battery in 1964 averaged 7 dwts. 13 grains in the sands.

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SOUTHERN PART OF KOOLINE LEAD FIELD

by J. L. Daniels

ABSTRACT

The geology of the southern part of the now abandoned Kooline Lead Field is summarized. Proterozoic shales and greywackes have been folded and the resultant axial plane cleavage is the main direction along which lead mineralization has developed.

INTRODUCTION

Ellis (1951) briefly described the Kooline Lead Field giving details of some of the mines production to August 31, 1949, local conditions, and prospects for the field. Since that date all the mines have closed down. The area described is the southern part of the field between Peak Edgar and Mt. Mortimer (Plate 33).

GEOLOGY

Recent mapping in the Hamersley Ranges (MacLeod and others, 1963; Halligan and Daniels, 1964) and radiometric age determinations (Leggo and others, 1965) show that the host rocks for the mineral veins in the Kooline Lead Field are of Lower Proterozoic age and not Archaean as previously thought. An age determination on galena from the Silent Sisters mine, in the northern part of the field, gave 1700 ± 150 million years (Riley, quoted in Leggo and others, 1965). It is thought that this also applies to the galena mineralisation in the southern part of the field.

The host rocks in the southern part of the field are shales and greywackes of the Ashburton Formation, the youngest formation of the Wyloo Group. They have been described in moderate detail by Halligan and Daniels (1964).

The fresh shale is pale grey and shows very fine sedimentary banding, either as parallel planes or as fine current bedding. On weathering the rock becomes dark brown and the bedding obscure.

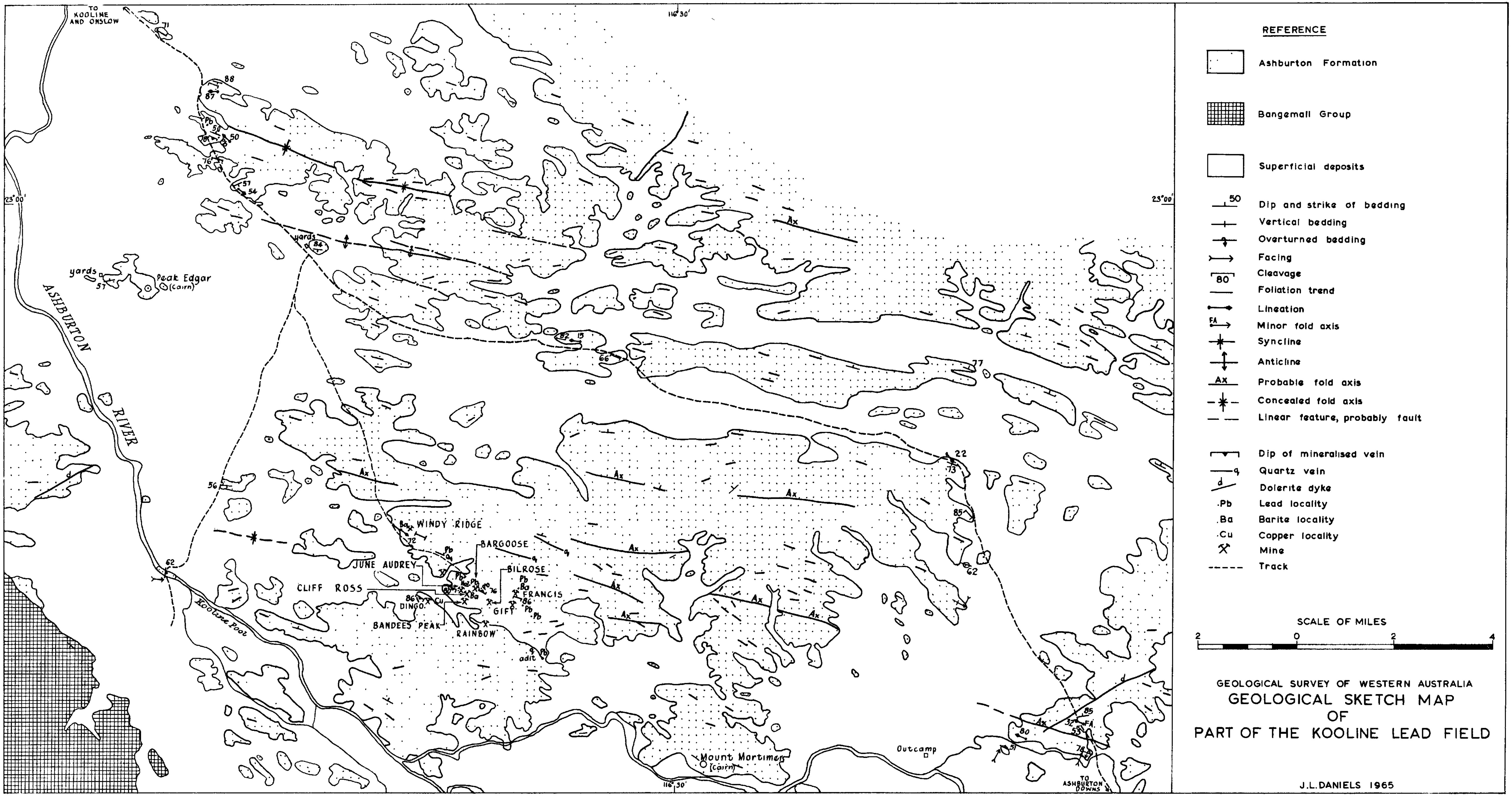
The greywacke beds are usually thin (6 to 18 inches thick) and occur interbedded with shale. The soles of the greywacke beds frequently show flute casts and groove casts. Graded bedding is common. The beds are interpreted as turbidites and measurements of the bottom structure directions indicate a provenance lying to the east.

Folding, during the Ophthalmian Fold Period, has impressed on these shales and greywackes a strong and persistent axial plane cleavage. This cleavage is the dominant structural feature of the area and is the main direction along which the mineralisation has developed.

Sedimentary bedding dips, where discernible, are usually of the order of 50° to 80°. Overturned bedding is known. Several major folds have been determined in the area and it appears that the majority of the mine workings occupy the axial region of a single fold, most probably a syncline (Plate 33).

Some of the lead veins have previously been described by Ellis (1951). Generally all are similar in that they are near-vertical veins from a few inches to approximately four feet thick and up to 200 feet long. Galena and quartz are the commonest minerals in the vein, but moderate amounts of barite and calcite are also present. Secondary cerussite appears to be widespread and locally abundant, both in the vein and throughout the wall rocks.

Apparently the method of working was to extract the vein material and hand pick the galena. Once the galena in the vein had petered out no deepening of the pit was undertaken to locate more concentrations of galena at greater depth. In the bigger mines e.g. Gift and Bilrose, the vein material was crushed and the galena concentrated on a Wilfley table. Any cerussite was concentrated by this method with the galena, but apparently no attempt was made to crush and concentrate wall rock with cerussitic impregnations. A sample from the dump of the 'Francis' mine (Plate 33), showing galena and cerussite impregnations in a (?) greywacke probably taken from the wall rock, assayed 19.3% Pb and 8 dwt, 20 grains of Ag per long ton.



GEOLOGICAL SURVEY OF WESTERN AUSTRALIA

GEOLOGICAL SKETCH MAP OF PART OF THE KOOLINE LEAD FIELD

J.L.DANIELS 1965

9076

RECOMMENDATIONS

To the west of the main workings there is a large area of flat alluvium which almost certainly covers the possible westerly extension of the field (Plate 33). This should be investigated possibly by geophysical methods. It may also prove valuable to extend this survey to include the known mines in anticipation of finding downward continuations of the veins. Sampling of wall rocks and testing for cerussite impregnations should not be neglected in any further work on the field.

PRODUCTION

Mining ceased on the field in 1959. The appended table lists the production from each show. Some of these have been identified on the accompanying map. The remainder may be found on the Mines Department Public Plan No. S.P. 127.

ACKNOWLEDGMENT

The writer wishes to thank Mr. George Hands for his assistance in the field.

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LEAD ORES AND CONCENTRATES
REPORTED PRODUCTION FROM KOOLINE CENTRE, ASHBURTON GOLDFIELD

No. of Lease Claim or Area	Name of Lease	Name of Holder	Period	MINE TREATMENT		PRODUCTION REALISED					Total Value F.O.B. £
				Ore Treated Est. Tons	Concentrates Therefrom Est. Tons	Ore & Conc. N.D.W. Tons	Assay and Lead Content		Payable Silver Content		
							Tons	Value F.O.B. £	Fine oz.	Value £	
M.L. 118	Bilrose	Rose & Davies	1948/1959	431·00	72·50	458·99	328·11	32,430·17	4,503·70	1,420·44	33,850·61
M.L. 119	Bandys Peak	Perry, Camp, Rose & Davies	1948/1951	....	....	56·37	45·59	4,577·64	186·18	23·80	4,601·44
M.L. 120	Kooline Queen	Camp & Dunlop	1948/1954	361·00	48·50	79·91	58·58	5,422·80	451·26	97·89	5,520·69
M.L. 121	South Kooline	M. E. Gray	1948/1954	....	....	93·47	60·56	5,386·10	596·71	110·74	5,496·84
M.L. 122	Gift	Camp & Party	1948/1957	7,749·00	1,164·00	1,214·69	932·03	104,448·93	8,362·07	2,548·23	106,997·16
M.L. 123	Phar Lap	B. Perry	1949/1953	118·00	16·85	15·55	10·26	897·25	137·16	37·07	934·32
M.L. 124	Silver King	Camp, Perry, Griffiths & Johansen	1948/1952	....	....	36·24	24·39	2,521·57	175·48	31·47	2,553·04
M.L. 127	Carnegie	J. H. Brown	1949	....	....	1·73	1·26	82·65	15·14	2·95	85·60
M.L. 133	Mt. Conspicuous	A. Townsend	1949	....	....	0·59	0·43	28·05	5·16	1·00	29·05
M.L. 135	June Audrey	Holben & Party	1949/1955	3,883·00	431·50	586·49	627·54	46,700·34	4,490·65	1,191·17	47,891·51
M.L. 136	Big Chief	J. E. Francis	1950/1952	....	....	22·10	7·91	725·60	12·94	....	725·60
M.L. 138	Rainbow	Camp & Party	1952/1953	....	....	8·19	6·04	433·68	59·86	19·62	453·30
M.L. 140	Beadon	Hill & Perry	1951/1953	....	....	102·41	68·57	8,855·35	575·79	169·31	9,024·66
M.L. 142	Mt. Conspicuous	Grey, Francis, Herrick & Curlyon	1950	....	....	2·04	1·36	89·35	13·06	2·70	92·05
M.L. 143	Dingo	Camp & Party	1951/1958	1,799·00	250·00	289·04	209·38	18,705·54	2,318·23	799·00	19,504·54
M.L. 155	Ridge	Rose & Johnson	1949/1957	....	....	263·84	205·11	16,211·96	1,934·79	550·63	16,762·59
M.L. 156	Roebuck	A. James	1951/1956	....	....	41·91	29·23	2,895·48	303·74	97·95	2,993·43
M.L. 161	Campsite	Camp & Party	1956/1957	55·00	8·25	8·68	6·10	660·40	59·41	22·95	683·35
M.L. 163	Redcraze	Camp & Party	1957/1958	350·00	55·00	57·70	44·69	3,975·09	394·88	159·11	4,134·20
M.C. 3	....	Camp & Dunlop	1948/1949	....	....	16·05	10·92	1,083·73	121·24	19·45	1,103·18
P.A. 200	....	Hamilton, Dunlop & Camp	1948	....	....	27·52	20·80	1,609·06	203·66	26·65	1,635·71
P.A. 213	....	Bargoes Synd. (Francis & Party)	1948/1949	....	....	20·02	13·56	1,275·12	237·94	44·20	1,319·32
P.A. 213	....	Holben & Party	1949	....	....	26·64	18·14	1,155·95	233·10	45·70	1,201·65
P.A. 230	....	V. P. Joy & M. Brennan	1949/1951	....	....	24·52	16·71	1,526·16	196·40	35·05	1,561·21
P.A. 232	....	A. C. Bellchambers	1948/1949	....	....	7·71	5·40	575·75	143·06	12·25	588·00
P.A. 233	....	M. Brennan	1949	....	....	7·88	5·45	357·00	68·95	13·50	370·50
P.A. 239	....	E. Shanks	1949	....	....	9·62	5·81	606·15	99·57	20·85	627·00
P.A. 240	....	Ballard & Carson	1949	....	....	6·41	4·67	307·05	56·09	11·00	318·05
P.A. 244	....	E. Reck	1949	....	....	1·37	1·02	52·95	10·37	1·60	54·55
P.A. 260	....	Iverson & Crossley	1950	....	....	1·84	1·20	96·75	9·73	1·80	98·55
P.A. 262	....	Illingsworth, J. E.	1951	....	....	7·09	5·68	735·20	40·14	10·20	745·40
P.A. 270	....	Jenkin, A. J.	1952	....	....	2·07	1·57	242·97	16·33	5·20	248·17
P.A. 282	....	Coombes & Furvey	1952/1953	....	....	5·05	3·80	421·16	27·03	6·70	427·86
P.A. 283	....	Jensen & Jacobson	1953	....	....	5·21	3·41	210·92	22·03	4·46	215·38
P.A. 285	....	Donnelly Bros.	1952	....	....	4·45	2·48	344·89	18·69	3·71	348·60
P.A. 287	....	Ballard, Shanks & Howie	1953	....	....	2·16	1·60	96·61	11·02	2·48	99·09
P.A. 300	....	Green, E. W. & Woodsbey, D. C.	1954	....	....	26·57	18·87	1,120·74	159·41	40·38	1,161·12
P.A. 315	Roebuck Lead Mine	Jenson, J. (worked by Camp & Party)	1957	....	....	34·20	25·84	2,786·65	253·87	98·05	2,884·70
P.A. 316	....	Griffiths, F. A.	1957/1958	....	....	10·35	7·44	654·15	31·92	12·35	666·50
Crown Lands Kooline	....	Eldridge, M. (deceased)	1953	....	....	1·37	0·94	87·70	....	....	87·70
Do.	....	Downie, J. D.	1952	....	....	2·14	1·31	207·83	11·45	2·72	210·55
					TOTAL	3,590·18	2,843·76	270,602·44	26,568·21	7,704·33	278,306·77

SECOND PROGRESS REPORT ON THE BROCKMAN IRON FORMATION IN THE WITTENOOM—YAMPIRE AREA

by A. F. Trendall

ABSTRACT

This report follows on from one in the Geological Survey of Western Australia Annual Report for 1964, and uses nomenclature defined there without further explanation. It reports mainly a detailed examination of crocidolite and riebeckite distribution in relation to structure and stratigraphy within a 15-foot section near the bottom of the basal Dales Gorge Member of the Brockman Iron Formation, along 1,800 feet of clean, continuous exposure. Four thick cherts at about 2-foot intervals in the lower part of the section contain thickened *macules,* thought to be concretionary structures. The central two of these four *maculate bands* are largely replaced by massive riebeckite. Riebeckite replacement is immediately related to a regular pinching and swelling of the maculate bands, with a constant wavelength of 5 feet and an axial direction 020°. In the upper part of the 15 feet there is no pinching and swelling, but all bedding surfaces are curved into similarlv trending *duplicate corrugations* with the same wavelength and an amplitude of 1 to 2 inches. The crestal planes of the corrugations dip east-southeastwards, and the structural details of each corrugation (in particular distinctive *cross-podded structures*) are repeated with extreme precision about 350 times in consecutive corrugations along the 1,800 feet of the gorge studied. This duplicate structural trend is one of the controls of crocidolite growth. A brief re-examination of the Dales Gorge Member at Wittenoom and Yampire Gorges suggests that the same structures, with the same axial trend, probably exert the same control over crocidolite growth throughout a wide area. It is possible to estimate the time relationships of compaction, mesobanding, macules, magnetite, duplicate structures, riebeckite and crocidolite with reasonable accuracy. Surprisingly, crocidolite does not appear to overlap in time with the structures which control it. An immediate economic application of the results reported is that asbestos assays from drilling may give grossly misleading results in exploration or ore evaluation.

INTRODUCTION

This is a second report on the progress of a continuing study whose main objective is the provision of a sound theoretical basis for the economic geology of iron formations of the Hamersley Group, with special emphasis on crocidolite. The reader is referred to the first report (Trendall, 1965) where details of the Australian Blue Asbestos Company's drilling programme at Wittenoom and Yampire, with an analysis of its stratigraphic results, a summary of the petrography of the unoxidised Brockman Iron Formation, and a depositional hypothesis for this formation involving major diagenetic modification and cyclic seasonal deposition, are given. For the regional geological setting and an internal stratigraphic subdivision of the whole formation, the reader is referred to a report by G. R. Ryan and J. G. Blockley (1965), who carried out field mapping during 1965 as part of the same study. Ryan and Blockley have distinguished the lowest part of the Brockman Iron Formation, with which the whole of both this and the earlier report are concerned, as the Dales Gorge Member, and this term is used here wherever appropriate. My own contribution during 1965 included: (1) Continuation of petrographic study of the unoxidised formation, with particular attention to those facies grouped as "shales" in the first report; (2) Preliminary study of crocidolite fibre structures; (3) Interpretation of the previous depositional hypothesis in chemical terms; (4) Study of small-scale distribution of riebeckite in relation to petrography and structure in the field at restricted localities (Dales Gorge and Yampire Gorge) chosen for the high quality and continuity of exposure at the required stratigraphic levels. Parts of this work are to be published separately; the main substance of this present report is an account of the results of item 4, above, but a summary discussion of progress on some of the general problems involved is also included.

THE YAMPIRE RIEBECKITE ZONE OF THE DALES GORGE MEMBER

In the first report the "lower riebeckite zone" of the Brockman Iron Formation was defined and the distribution of the main riebeckite-prone cherts within it was indicated (Trendall, 1965, p. 60-61 and Plate 32). In Ryan and Blockley's (1965) revised terminology this is now the Yampire Riebeckite Zone of the Dales Gorge Member. No systematic account of crocidolite occurrence within the zone was given. In this section a more complete catalogue of riebeckite-prone cherts is presented, extending down to the third fibre seam; attention is drawn to the existence of two distinct types of occurrence of crocidolite in relation to the riebeckite mesobands; an indication is given of lateral variation of the main riebeckite and crocidolite levels between Wittenoom, Yampire and Dales Gorges; and equivalence with previous nomenclature is summarised.

Previous nomenclature

K. J. Finucane (1939) was the first to give stratigraphic information on crocidolite and riebeckite in (what is now) the Dales Gorge Member of the Brockman Iron Formation. Finucane's stratigraphic sections for Wittenoom, Yampire and Dales Gorges are shown in Plate 34, together with his more recent (Finucane, 1964) section for Wittenoom Gorge and later nomenclature used at Yampire by A. B. A. geologists. The precise stratigraphic correlation of these sections first became known during 1964 as a result of the A. B. A. Co. drilling and Geological Survey of Western Australia mapping. On Plate 34 slight modifications of Finucane's sections have been made to clarify their relationship to the present nomenclature of the Dales Gorge Member, in the left-hand column.

Errata and addenda

Attention is now drawn to two closely related errors in the first report. The knapping seam is not equivalent to the third fibre seam (Trendall, 1965, p. 57, table at top of right-hand column). As shown on Plate 34 of this report the knapping seam (or 'main seam' of Finucane, 1939) lies just below the first 'shale'. The 'knapping seam marker' is a thick chert just above the knapping seam, and is not a 'shale' below the third or No. 3 seam. There is no 'shale' beneath the third seam, as shown on Plate 32 of the first report. In view of the continuity of b.i.f. between the base of the Dales Gorge Member (=base of the Brockman Iron Formation) and the first 'shale' this will be referred to as the 'basal b.i.f.'. The base of this lies some 45 feet below the base of the first 'shale'.

Future nomenclature

From Plate 34 it is clear that the past and current nomenclature of crocidolite occurrence is confusing. The Top Seam at Dales Gorge (Finucane, 1939), for example, is equivalent to the Upper Seam of the main Yampire series at Yampire (former A. B. A. usage) and part of the Yampire C Seam (current A. B. A. usage) at Wittenoom. It consists of two mesobands of crocidolite just above and below a thick and laterally persistent riebeckite. On the other hand the Upper Seam (Finucane, 1964; Trendall, 1965; A. B. A. usage) at Wittenoom is equivalent to the Lower Seam of the main Yampire series at Yampire (former A. B. A. usage) and is not named at Dales Gorge (Finucane, 1939). It consists of a cluster of crocidolite mesobands over a narrow stratigraphic range within which lateral correlation is difficult.

The numerical nomenclature of the macrobands in the Dales Gorge Member proposed in the first report has found general acceptance, and it no longer appears necessary to give formal names to the 4th and 15th 'shales', as was anticipated (Trendall, 1965, p. 57 and Plate 32). Some similar systematic method of denoting individual mesobands of all types or groups of mesobands is now needed.

It had been intended to suggest in this report a numbering system for mesobands within the numbered macrobands, based on average height above the base of each b.i.f. macroband (=top of 'shale'). An alternative possibility, the designation of one unbroken drill core as a type section of the Dales Gorge Member, now seems to have advantages. In particular it would ensure great precision, it would enable both metres and feet to be used with precise equivalence, and it would give more flexibility for future requirements which cannot be foreseen now. At present it appears that the Dales Gorge Member, where stratigraphic specification to a few millimetres is possible over many thousands of square miles, raises problems of nomenclature which are new to stratigraphy. In this report these are temporarily avoided by using short descriptive phrases.

Stratigraphic levels and lateral variation of crocidolite and riebeckite

The stratigraphic column at the left-hand side of Plate 34, a modification and extension of that of Plate 32 of the first report, shows the principal riebeckite-prone cherts and the main levels of crocidolite development. This column is compiled from core logging by A. B. A. Co. geologists, information from G. R. Ryan, and my own core and field examination. Crocidolite mesobands fall very clearly into two types: those which lie immediately above or below massive riebeckite and those which occur away from riebeckite. The only clear instances of the second group are in the upper and lower seams. In 15 recent boreholes of the A. B. A. Co's programme in the Wittenoom and Yampire areas, 21.2% of all fibre between the 2nd and 3rd 'shales' is immediately adjacent to massive riebeckite. Of the remaining 78.8% of fibre, 95.8% (75.5% of the total) lies within the upper seam. Thus only 3.3% of the total fibre in this stratigraphic range falls outside a broad two-fold division of crocidolite into that associated with massive riebeckite and that of the upper seam.

I recorded earlier (Trendall, 1965, p. 61) a failure to find any simple pattern in the areal distribution of riebeckite or any correlation between the measurable variables (e.g. macroband thickness, thickness of massive riebeckite, fibre length) of the Yampire Zone. During 1965, 15 more holes were drilled to give a total of 33 reliably logged holes for such exploratory testing. The correlations which have now been tested graphically and which show an apparently random scatter of points on the graph are listed below. T b.i.f.2 means the stratigraphic thickness of the 2nd b.i.f.; R and F indicate massive riebeckite thickness and fibre length (upper seam only):

Abscissae	Ordinates
F b.i.f. 2	T b.i.f 2
F b.i.f. 2	T b.i.f 2 + 3
F b.i.f. 2	R b.i.f. 2
F b.i.f. 2	R b.i.f. 3
F b.i.f. 2	R b.i.f. 2 + 3
F b.i.f. 2	R b.i.f. 2/R b.i.f. 3
T b.i.f. 2	R b.i.f. 2
T b.i.f. 3	R b.i.f. 3
T b.i.f. 2 + 3	R b.i.f. 2 + 3
R b.i.f. 2	R b.i.f. 3
T b.i.f. 2	T b.i.f. 3

All these correlations are at the whole macroband scale. Mr. B. Chapple informs me that during drilling in a restricted part of the Wittenoom area there appeared to be a direct correlation between the length of fibre in the upper seam with distance of the first massive riebeckite mesoband above the seam, provided that the core was generally rich in riebeckite. To test a comparable correlation I plotted the ratio of riebeckite in the lower and upper parts of the 2nd b.i.f. against fibre lengths of the upper seam and obtained a distinct negative correlation. Of 31 holes plotted, the 23 with more riebeckite in the upper part than the lower had a mean fibre length of 1.73 inches (range 0.35 to 4.44), while the 8 holes with more riebeckite in the lower part than the upper had a mean length of 0.70 (range 0.00 to 2.52).

The immediate deduction may appear to be that, if riebeckite of all kinds formed from soda in immediately local connate water, then the use of all the soda to form massive riebeckite would inhibit later crocidolite growth. However, the situation appears to be more complex than this, and is discussed later.

On a broad scale the Yampire Riebeckite Zone shows wide variations. As an example, massive riebeckite is abundant in the first b.i.f. at Dales Gorge but crocidolite is barely represented in the upper and lower seams. At Yampire and Wittenoom crocidolite is present in both these seams, but there is virtually no massive riebeckite in the first b.i.f. To find some scale at which the distribution of riebeckite and crocidolite was demonstrably related to some other geological factor, the detailed study at Dales Gorge, which is reported on in the following section, was carried out.

THE DALES GORGE SECTION

A detailed description of riebeckite distribution and structures related to it, within a restricted area possessing the clean and laterally continuous exposure essential for further study of this problem, is given here; an interpretation of the evidence presented is made later.

General

This study was confined to a 1,800 foot length of Dales Gorge, measured east-southeastwards from a large tree at the corner of a branch gorge leading from Circular Pool (see Plate 35). Localities cited as, for example, 450 feet, refer to the distance down the gorge from this tree. Finucane (1939, Plate 3) gives a map of Dales Gorge; this present report is concerned only with the part of the gorge along Cotter's and Mahlberg's claims.

The study was confined stratigraphically to the first b. i. f. (Trendall, 1965, Plate 32); more specifically, the following descriptions are concerned almost entirely with the 15 feet between its base at the top of the first 'shale' and a level 4 feet below its top at the base of the second 'shale'. Petrographically the rocks consist of an alternation of the various mesoband types described in the first report (Trendall, 1965, p. 62, 63), but there is a tendency for a regular alternation of thick (3 to 6 inches) flat-modified cherts with thinner (total 2 to 4 inches) alternations of 5 or 6 mesobands of QIO and primitive chert (Plate 39).

Structure

In the part of Dales Gorge shown in the inset of Plate 35 the lowermost (not numbered) b.i.f. appears in two windows framed by the first 'shale'. In the part of the gorge studied in detail there is a general gentle south-southwesterly dip. The three values shown on Plate 35 (map C: 1° 52', 3° 11', 1° 45') were recorded at points where the vertical rise of a bedding plane over some tens of feet could be measured accurately using the level of a pool. This south-southwesterly dip is a part of the regional structure (MacLeod and others, 1963). Open cross-folds whose axes also plunge gently south-southwest (Plate 35; Map B) would be difficult to detect if exposures were less perfect. A gentle corrugation of bedding surfaces, the 'regional rippling' of Plate 35 (diagram E) runs at about 110° and is related to the Ophthalmian folding of Halligan and Daniels (1964). Its intensity varies through the section, but it is nowhere conspicuous.

The main joint directions, which control the directions of the gorge, are also shown in Plate 35, together with the directions of various minor structures described below.

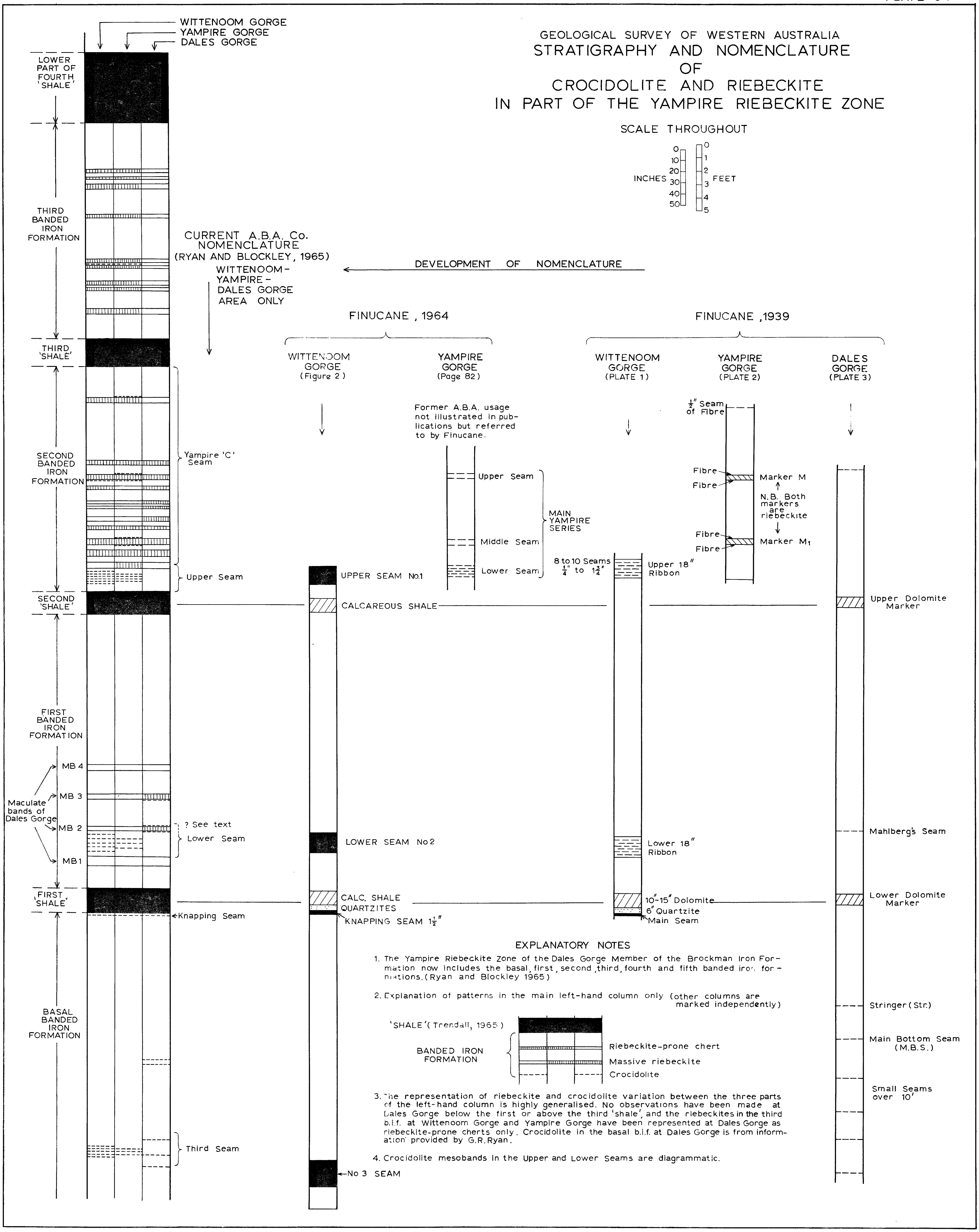
Macules and maculate bands in the stratigraphy

Definitions. The term *macule* is here applied to an abrupt local thickening of a limited stratigraphic thickness of b.i.f., usually involving a restricted upward and downward bulge of a thick flat-modified chert mesoband into the adjacent levels. Macules are commonly restricted to specific levels in which they are abundant, with few or none in the immediately adjacent b.i.f. The term *maculate band* is proposed for a mesoband or group of mesobands within which macules are concentrated. The follow-account of macules includes some observations outside Dales Gorge.

Stratigraphic relationships. There are four main maculate bands in the first b.i.f. at Dales Gorge. These bands correspond roughly (see below) with the main riebeckite-prone cherts, and their positions are shown as such in Plate 34. On Plate 35 (Map A) the principal clean gorge-floor pavements, which expose the upper and lower surfaces of these bands, are shown, together with other features of the structure and stratigraphy. For brevity these four bands are referred to here, from below upwards, as

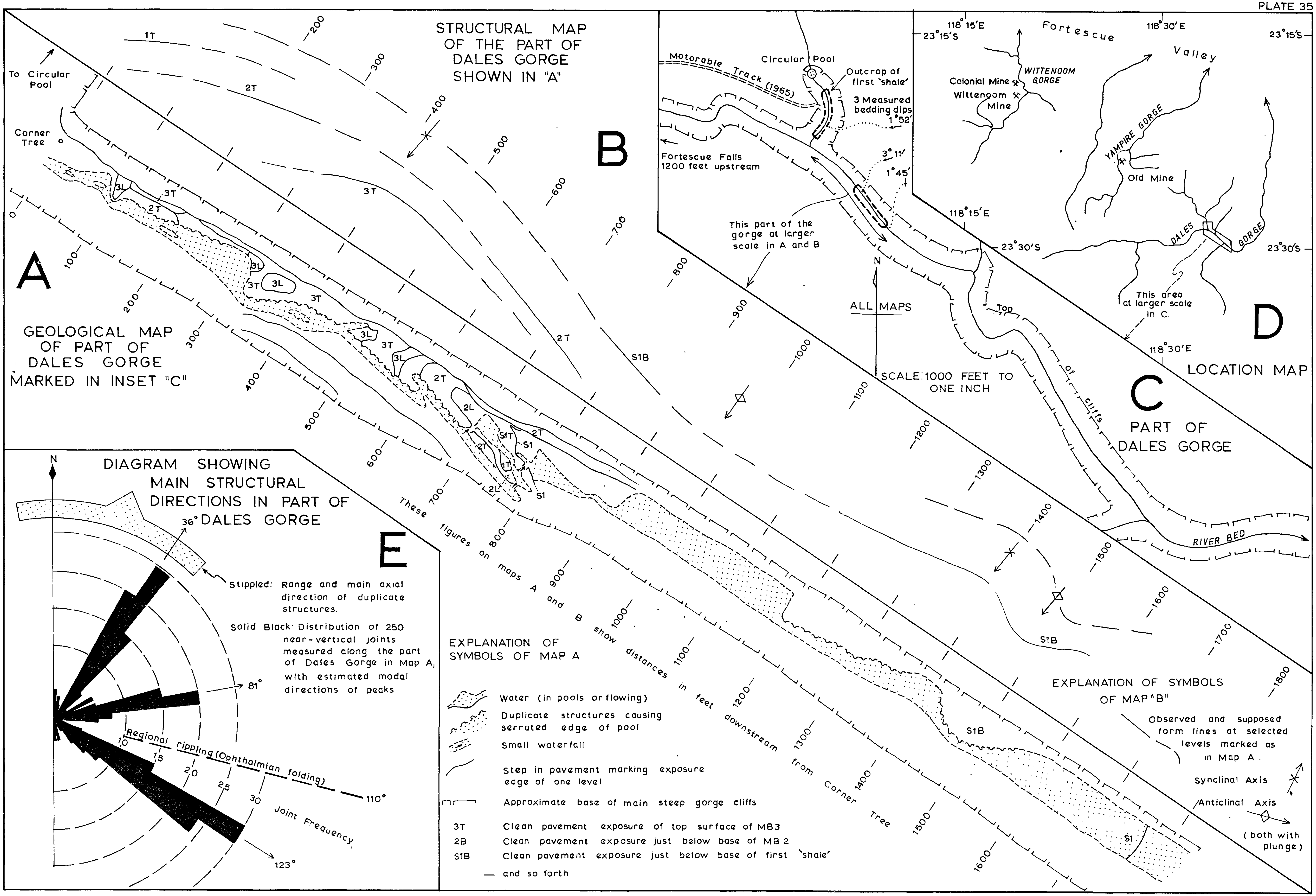
GEOLOGICAL SURVEY OF WESTERN AUSTRALIA

STRATIGRAPHY AND NOMENCLATURE OF CROCIDOLITE AND RIEBECKITE IN PART OF THE YAMPIRE RIEBECKITE ZONE



EXPLANATORY NOTES

1. The Yampire Riebeckite Zone of the Dales Gorge Member of the Brockman Iron Formation now includes the basal, first, second, third, fourth and fifth banded iron formations. (Ryan and Blockley 1965)
2. Explanation of patterns in the main left-hand column only (other columns are marked independently)
3. The representation of riebeckite and crocidolite variation between the three parts of the left-hand column is highly generalised. No observations have been made at Dales Gorge below the first or above the third 'shale', and the riebeckites in the third b.i.f. at Wittenoom Gorge and Yampire Gorge have been represented at Dales Gorge as riebeckite-prone cherts only. Crocidolite in the basal b.i.f. at Dales Gorge is from information provided by G.R. Ryan.
4. Crocidolite mesobands in the Upper and Lower Seams are diagrammatic.


STRUCTURAL MAP OF THE PART OF DALES GORGE SHOWN IN "A"
B
To Circular Pool
Corner Tree
1T
2T
3T
3L
S1B
S1T
S1
2L
1T
A
GEOLOGICAL MAP OF PART OF DALES GORGE MARKED IN INSET "C"
These figures on maps A and B show distances in feet downstream from Corner Tree
Circular Pool
Motorable Track (1965)
Outcrop of first 'shale'
3 Measured bedding dips
1°52′
3°11′
1°45′
Fortescue Falls 1200 feet upstream
This part of the gorge at larger scale in A and B
N
ALL MAPS
SCALE: 1000 FEET TO ONE INCH
Top of cliffs
RIVER BED
C
PART OF DALES GORGE
118°15′E
118°30′E
23°15′S
Fortescue Valley
Colonial Mine
Wittenoom Mine
WITTENOOM GORGE
YAMPIRE GORGE
Old Mine
DALES GORGE
23°30′S
This area at larger scale in C.
D
LOCATION MAP
DIAGRAM SHOWING MAIN STRUCTURAL DIRECTIONS IN PART OF DALES GORGE
E
36°
81°
110°
123°
Regional rippling (Ophthalmian folding)
10
15
20
25
30
Joint Frequency
Stippled: Range and main axial direction of duplicate structures.
Solid Black: Distribution of 250 near-vertical joints measured along the part of Dales Gorge in Map A, with estimated modal directions of peaks
EXPLANATION OF SYMBOLS OF MAP A
Water (in pools or flowing)
Duplicate structures causing serrated edge of pool
Small waterfall
Step in pavement marking exposure edge of one level
Approximate base of main steep gorge cliffs
3T Clean pavement exposure of top surface of MB3
2B Clean pavement exposure just below base of MB 2
S1B Clean pavement exposure just below base of first 'shale'
— and so forth
EXPLANATION OF SYMBOLS OF MAP "B"
Observed and supposed form lines at selected levels marked as in Map A.
Synclinal Axis
Anticlinal Axis
(both with plunge)

MB1, 2, 3, and 4. Macules are present also in the band overlying MB4, and just above and below both MB2 and MB3, but they are sufficiently more abundant and persistent at the four levels specified to justify the nomenclature.

There are laterally consistent differences between these four bands. MB1 is between 6 and 11 inches thick and consists of a single flat-modified chert mesoband with little division apart from the curious quartz 'stylolite' noted below. MB2 and MB3 are both between 3 and 8 inches thick, and include a mesoband of flat-modified chert with a thickness of about 3 inches and an overlying succession of several alternations of QIO and thin primitive or pod cherts. MB4 is a single flat-modified chert 4 to 7 inches thick. As described below, MB4 has fewer macules than the other maculate bands, while MB2 and MB3 are more susceptible to riebeckite replacement.

From Plate 34 the maculate bands appear to recur at stratigraphic intervals of about 2 feet. Although macules are known to occur at other levels in the Dales Gorge Member it is not yet known whether this regularity is an invariable feature of their occurrence.

Area distribution. It is difficult to specify areal macule density accurately, since macules tend to range downwards in size or perfection of development to a point where they must cease to be ranked equally with the bigger macules for counting. MB1, MB2 and MB3 all have between 3 and 4 macules per square yard (Figure 26), although MB1 (Plate 36, D) has, by subjective judgment, slightly fewer, but larger, macules than either MB2 or MB3. MB4 very clearly has fewer macules: probably less than one per square yard. There is no ordered pattern apparent in the distribution of macules; it seems to be random and, on a scale suited to their size, quite even.

Shape and surface expression. Macules are circular in plan. There is no significant development of polygonal, ovoid or irregular form. Their structure can therefore be represented completely by a vertical median cross-section. There is most commonly an equal upward and downward bulge, of the proportions shown in Figure 24, A. Some macules bulge more up than down, and others more down than up (Figure 24, B and C). In macules developed in maculate bands which consist of groups of mesobands, one or more of the thin upper chert mesobands may be thickened over a larger radius than the bulk of the macule (Figure 24, D). When eroded to appropriate levels, such macules appear as discoid forms (Plate 36, C), or as shallow circular depressions (of erosion to levels X and Y in Figure 24, D).

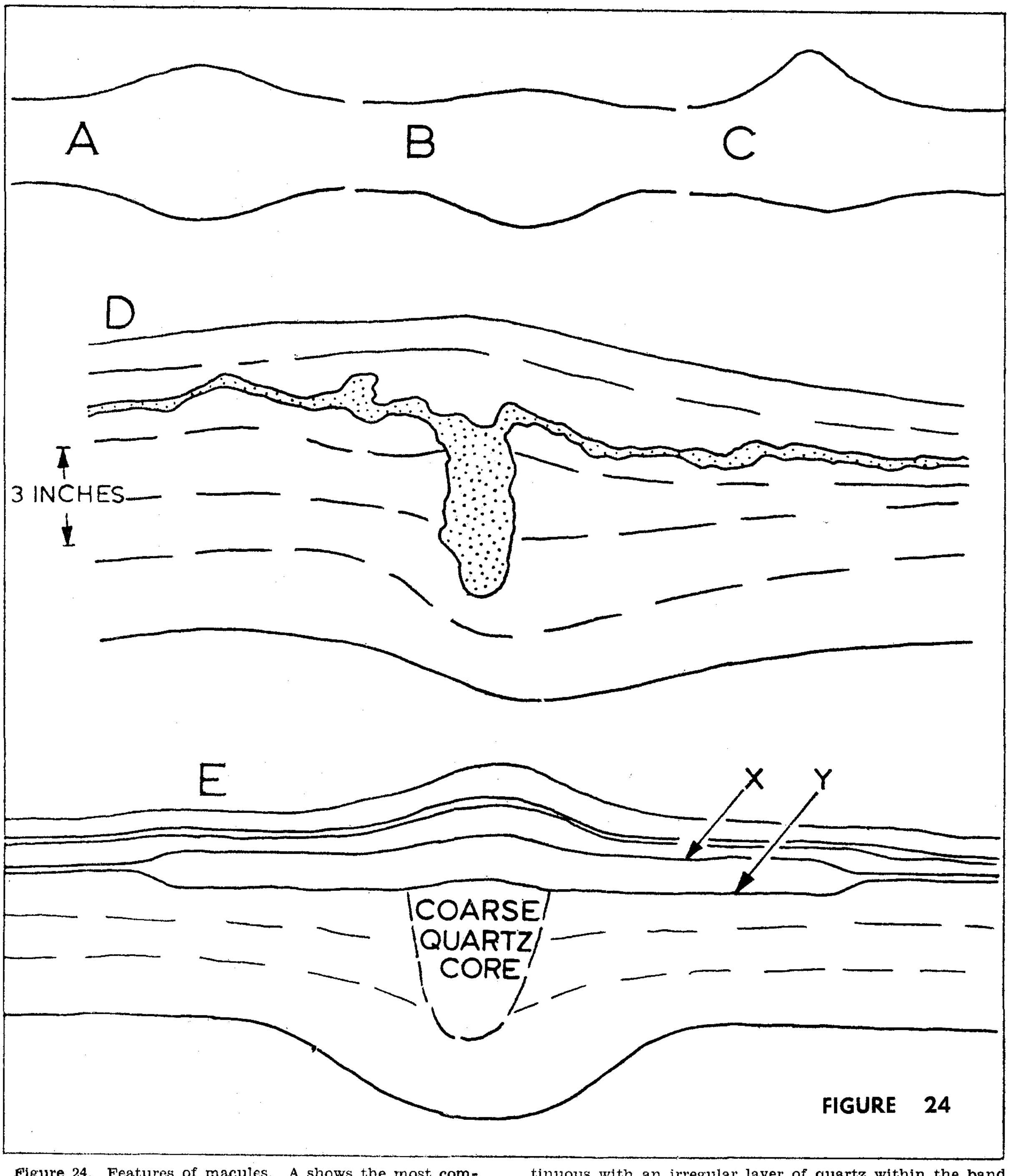


Figure 24. Features of macules. A shows the most common proportions of macules, B and C are variants. All three are from sketches at Dales Gorge. The immaculate width of the band is about 5 inches in each case. D shows the characteristic structure of macules in MB1 at Dales Gorge, with the coarse quartz (stippled) core continuous with an irregular layer of quartz within the band. The diagrammatic vertical cross-section E shows the origin of disc-like forms on exposure of macules in bands consisting of a thick flat-modified chert below and several thinner chert mesobands above. See text for further explanation.

Macules are closed structures. The higher mesobands of macules in composite maculate bands, or the uppermost and lowermost microbands in single mesoband maculate bands, and in both cases the immediately overlying and underlying mesobands, are all continuous and unbroken round the macule. Normally, on exposure of the surface of a maculate band, the vulnerable macule tops are broken away to reveal internal microbanding or fine mesobanding (Plate 36, D); they then give the impression of volcano-like structures (Plate 36, A). Whereever good cross-sections are exposed they have closed continuous tops. The unbroken surface appearance varies quite widely between smoothly curved domes, with or without radial furrows or striations (Plate 36, A), and forms with summit depressions encircling a central boss (Plate 36, B).

Where macule centres are sufficiently close to cause overlap there is no increase of thickness or any apparent interference; the macules merge together with negligible mutual distortion (Plate 36, C).

Size. Macule size is difficult to record since they have no easily specifiable lateral limits. Plates 36, 37 and 38 offer an impression of the size ranges of macules at Dales and Yampire Gorges. In the upper part of Wittenoom Gorge, macules 15 feet high are developed at the base of the 15th b.i.f., and include many mesobands. These project downwards into and distort the whole of the underlying 15th 'shale'. One appears in Figure 12 of MacLeod (1966), above and to the right of the man. On the other hand there appears to be no lower limit to macule size; this point is taken up again later.

Internal structure. Median vertical cross-sections of macules are shown in Plates 37 and 38. The thickest part of the macule has always within it a restricted volume, either cylindroidal (Plate 37, A), pipe-like (Plate 37, C; Plate 38, B), or bowl-shaped (Plate 38, A), in which the average thickness of microbanding is about 1.0 to 1.7 mm. Although the microbanding of the maculate band is continuous through all parts of each macule, this coarsely microbanded core is more or less sharply divided from the enclosing chert, and from its outer margins the microbanding curves evenly away down to the immaculate thickness of the band. In the five macules shown in Plates 37 and 38 the mean ratio of greatest to least microband thickness is 2.60, with extremes of 2.00 (Plate 37, A: the simplest form) and 3.04 (Plate 37, C). In pipe or bowl-shaped cores, the microband thickness of the chert in the innermost 'cavity' is intermediate between those of the core and the immaculate chert (Plate 37, C; Plate 38, A and B). The axis of the central core (and of the macule) is most commonly at right angles to the bedding, but tilts up to 25° occur. At Dales Gorge I noted no preferred direction of tilt but made insufficient observations for statistical treatment.

The marginal chert of macules has the normal petrography of flat-modified cherts (Trendall, 1965, p. 62-63) inwards to the edge of the core. Although in all macules so far thin-sectioned the most coarsely microbanded parts are quite strongly replaced by riebeckite, their main petrographic differences appear to be a very slight coarsening of the quartz mosaic (to about 25 to 30 microns), absence of carbonate and magnetite, and abundance of apatite; this, with dusty hematite platelets, is often the principal defining material of the microbanding. It is in the innermost 'cavity', of intermediate microband thickness that there is most petrographic difference. Here there may be an irregular quartz mosaic of average grain diameter about 4 mm associated with coarse irregular clotting of carbonate, riebeckite, and apatite. The microbanding, which may be sharply distorted (Plate 38, B: the upper part of the core) is defined mainly by riebeckite and sometimes almost obliterated. In MB1 at Dales Gorge the central coarse quartz columns of the macules are continuous with an undulating layer of quartz ¼ to ½-inch thick which maintains an approximate stratigraphic level but transgresses the microbanding in the manner of a stylolite (Figure 24, E). The chert immediately outside macule cores often shows cracks obliquely cutting the microbanding, filled by quartz, magnetite or carbonate (Plate 37, B and C; Plate 38, A, top right). Irregular brittle disruption (Plate 38, B) is less common.

Duplicate structures

The general term *duplicate structure* is applied in this report to a number of closely related structures whose common characteristic is precise and regular repetition (duplication) at small horizontal intervals.

FIGURE 25

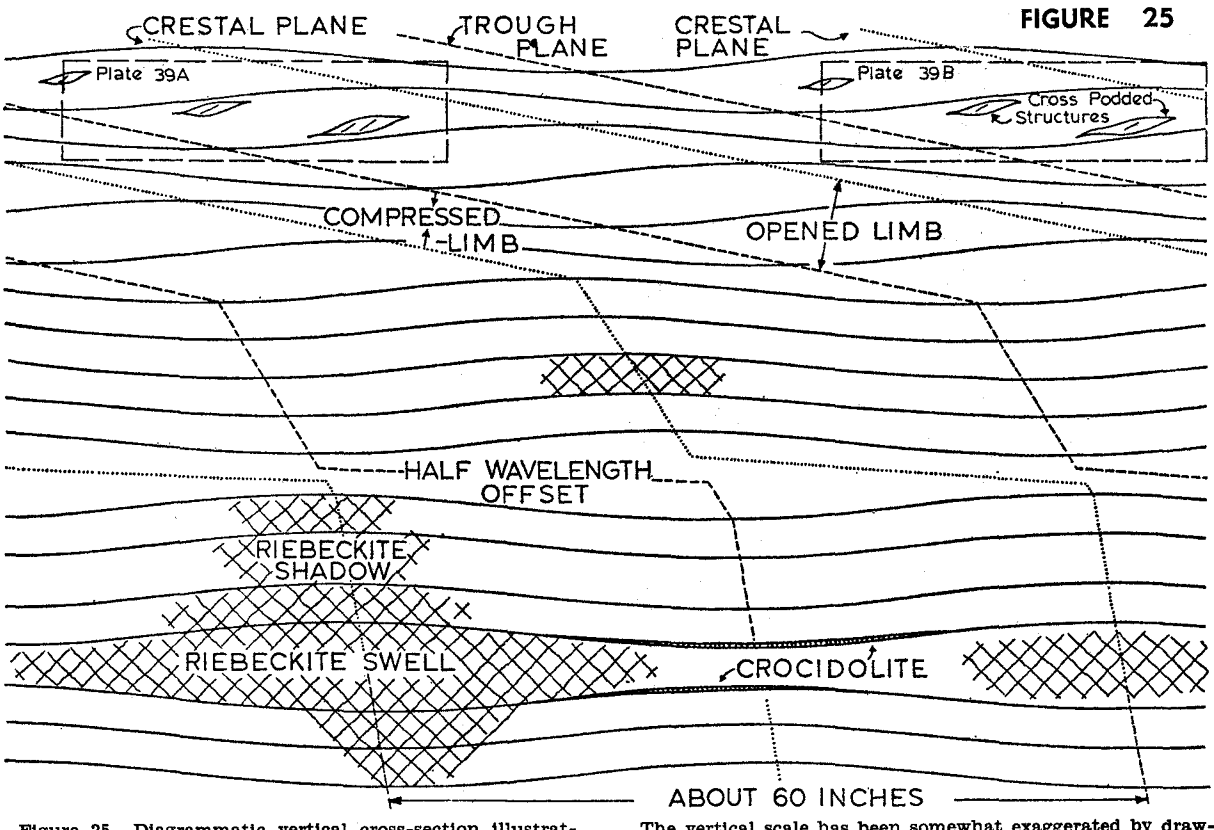


Figure 25. Diagrammatic vertical cross-section illustrating structures in the central part of the first b.i.f. at Dales Gorge, looking north-northeast. Duplicate corrugations with shallow easterly-dipping axial planes appear in the upper part, where the positions of A and B of Plate 39 relative to each other and to the corrugations are outlined. Two changes of axial plane slope are illustrated, one of them coincident with a half-wavelength offset causing pinching and swelling of the chert. In the lower part common shapes of riebeckite swells and shadows are shown. The vertical scale has been somewhat exaggerated by drawing all bedding planes with an amplitude (slightly under 2 inches) higher than the average, but less than the greatest measured. Although this is not an exact stratigraphic section the lower part represents a common situation along MB2 (see Plate 40), while MB4 could be one of the cherts (with riebeckite) mid-way up the section. At the top the shallowing of axial plane dip represents closely the situation between 4 and 6 feet above MB4, shown in part by Plate 39.

Duplicate corrugation. All bedding 'planes' (= major mesoband boundaries) in the part of the first b.i.f. studied at Dales Gorge, are gently corrugated. The corrugations are smoothly sinusoidal, with a wavelength of about 5 feet and an amplitude of 1 to 2 inches, and have an axial direction about 020°; these general data are amplified below. The axial direction of these structures is such that excellent vertical cross-sections, perpendicular to their trend, are available on vertical faces of the main joints running along the gorge (Plate 35, E). The corrugations are conspicuous on the smooth bedding plane pavements of the gorge floor and give a regular saw-tooth shape to the edges of pools beneath whose surfaces they dip (Plate 35, A). In Figure 14 of MacLeod (1966) they are easily picked out on the floor of the gorge in a photograph taken from some 300 feet vertically above.

As shown in Figure 25, the crestal plane of duplicate corrugations above MB4 may be inclined east-southeastwards at angles between about 17° and 70°. Locally there may be a sharp offset of half a wavelength in the continuity of the crestal plane within a thick chert, so that a crest on the upper surface corresponds with a trough in the lower, and the chert mesoband pinches and swells with the same regularity as the corrugations.

The wavelength of duplicate corrugations is very consistent. Measurements gave the following results:

Position in gorge	Stratigraphic level	Number of corru-gations measured	Total length	Wave-length (inches)	Ampli-tude (inches)
350–400 feet north side of floor	6 inches above top of MB4	10	51′ 2″	61·4	1·75
As above	17 inches above top of MB4	16	77′ 1″	57·9	1·5
600–700 feet south side of floor	6 inches above top of MB4	20	101′ 0″	60·6	2

The apparently smaller mean wavelength of the middle measurement is due to the inclusion of a short double crest close to a bifurcation (see *Areal shape,* below). The correspondence between the upper and lower measurements is a closer index of the regularity of the corrugations.

Cross-podding. As shown in Figure 25, the inclination of the crestal plane of duplicate corrugations leads to the presence of compressed and opened limbs. On the opened sides lenticular structures are locally developed between the main flat-modified cherts; they consist of a pile of thin 'S'-shaped cherts in a QIO matrix. The long middle limbs of the 'S's are paralled and inclined down from east-southeast to west-northwest (Figure 26, A). They resemble depositional cross-bedding, but as they probably developed solely by diagenetic compaction and consist of pod cherts, they are here called *cross-podded structures.* Plate 39, A and B are photographs of parts of the opened limbs of two successive duplicate corrugations with two complete cross-podded structures. Plate 39, C shows the same part of the fourth corrugation further east-southeast, while the salient features of all three photographs are sketched in Plate 39, D. In the 1,800-foot length of the gorge examined, about 350 similar, almost indistinguishable photographs could be taken, and other parts of each corrugation would serve equally well to show the astonishing perfection of structural repetition. In Figure 26 successive cross-podded structures, traced directly from the rock, are shown. Note that cherts are present in the structure which are absent away from it along the bedding.

Where a clean bedding surface is exposed just above or below a cross-podded structure, this appears as a ridge (cross-podding ridge) or trough running parallel to the general direction of the duplicate structures. The areal shape of these ridges is discussed below.

Riebeckite swells. It had already been noted that the abrupt offset of duplicate corrugations by half a wavelength may give rise to pinches and swells of a mesoband. Such bands are commonly the site of both macules and riebeckite replacement, which is often confined to the swells; the resulting elongated ribbons of massive riebeckite are called here *riebeckite swells.* MB3 frequently shows riebeckite swells. They give rise to particularly spectacular pavement exposures broadly striped in blue and pale grey. A single measurement of wavelength gave:

Position in gorge	Stratigraphic position	Number of swells	Total length	Wave-length (inches)
370–470 feet north side of floor	Top of MB3	20	98′ 9″	59·3

Details of riebeckite and crocidolite in relation to swells are given further below. Locally, cubes of pyrite about ½-inch across occur along the crests of swells.

Associated minor structures. Two minor structures associated with duplicate corrugations and riebeckite swells are noted here; surface cracking, and rippling. On many bedding surfaces of these structures there is a curious curving pattern of lines which roughly follow the trend of the duplicate structures but which converge over underlying macules rather like lines of a magnetic field. They are illustrated in Figure 27. Although locally they are defined by thin, surface lines of magnetite, they do not appear normally to penetrate deeply into the rock. The rippling structure, which is not unlike the corrugations of the Ophthalmian folding, is well displayed on MB3 at 100 feet in Dales Gorge. It runs parallel to the trend of riebeckite swells along the intervening troughs, and is defined by a gentle small-scale corrugation of the upper thin mesobands of the maculate bands in which the swells occur.

Areal shape. Although almost all duplicate structures at Dales Gorge have an average axial trend close to 020°, this is difficult to measure precisely since there is some local irregularity of direction, and occasionally bifurcation. The wavelength quickly recovers its habitual value and consistency away from such irregularities, and the corrugations have the appearance of gigantic ripple marks. The most accurate indication of local axial direction is given by cross-podding ridges. At one point (at 650 feet on a surface 10 inches below MB3) a ridge curves gently from 394° to 030° over 12 feet.

Riebeckite and crocidolite in relation to maculate bands and duplicate structures

Massive (mass-fibre) riebeckite. Attention has already been drawn to the approximate equivalence of maculate bands and riebeckite-prone cherts. This equivalence is shown in greater detail in Plate 40, where the extent of riebeckite development at the end of each of eighteen 100-foot intervals down the gorge (Plate 35) is shown by a semi-diagrammatic, vertical cross-section looking north-northwest representing approximately every twentieth duplicate swell. For convenience swells of each maculate band are shown vertically superposed, but this is not always so. MB1 is exposed only between 700 and 1,700 feet. It contains little riebeckite, and has only faint duplicate pinches and swells. Only at* 700 and 1,400 feet is riebeckite occurence related to swells; at 1,000 and 1,100 feet it occurs in association with macules irrespective of the position of these in the swells. MB2 consists of massive riebeckite throughout its exposed length, evenly pinching and swelling with the duplicate structures. Over two-thirds of this distance the two overlying flat-modified cherts, each about 4 inches thick, are also massive riebeckite. Elsewhere they only bear riebeckite over the swells; the term *riebeckite shadows* (Figure 25) is applied to this type of riebeckite occurrence. At 1,400 feet the three cherts below MB2 are also solid riebeckite for 12 inches downwards, with faint shadows continuing down to MB1; elsewhere, only shadows are present beneath MB2. Around 750 feet riebeckite shadows occur below MB2 on every *alternate* swell. At 1,100 and 1,600 feet it is the chert immediately above MB2 which shows the more conspicuous pinching and swelling. MB3 pinches and swells throughout the observed length. It is solid riebeckite only at 300 and 1,500 feet; elsewhere it has

* Here, and in the succeeding account, a feature described as at, e.g., 1,400 feet may be present from just over 1,300 to just under 1,500 feet. Gradations over intervening distances were not noted.

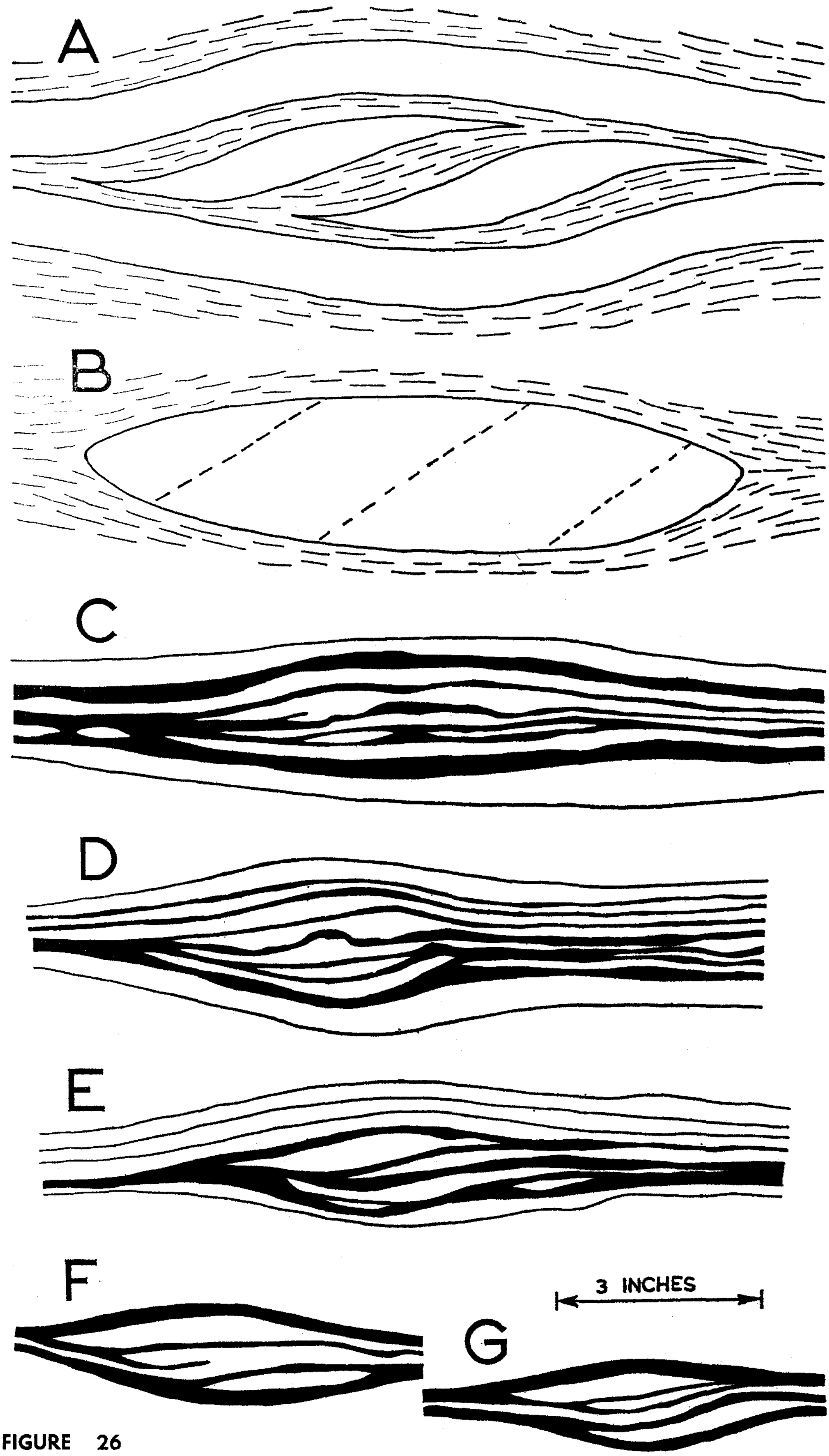


FIGURE 26

Figure 26. Features of cross-podded structures. A shows diagrammatically the structure of cross-podded structures at Dales Gorge, looking north-northeast at a vertical joint surface. The two internal S-shaped cherts of the structure do not extend outside it ,and have a thickened middle part which dips west-northwest. QIO has an ornament of dashed lines. B is a similarly oriented section of an unusual type of cross-podded structure from Yampire Gorge, 6 inches wide. A flat elongate chert ribbon with a smooth symmetrical external surface has oblique bedding marked internally by carbonate and hematite distribution. Note that the internal dip of the structure follows that of A. C, D, E, F and G are all based on tracings made from vertical joint surfaces (looking north-northeast) in the 1,800-foot length of Dales Gorge studied in detail. C, D and E, made close to 0 feet, 450 feet and 800 feet, respectively, show the structure of the cross-podded structure nearest the bottom right-hand corner of all illustrations on Plate 39. Thus D and E are about 90 to 160 corrugations further eastwards respectively than C. F and G both show the structure partly included near the top left-hand corner of all illustrations on Plate 39, at 0 feet and 450 feet. The scale above G applies to C, D, E, F and G. See also Figure 25 for the relative positions of the last five sketches.

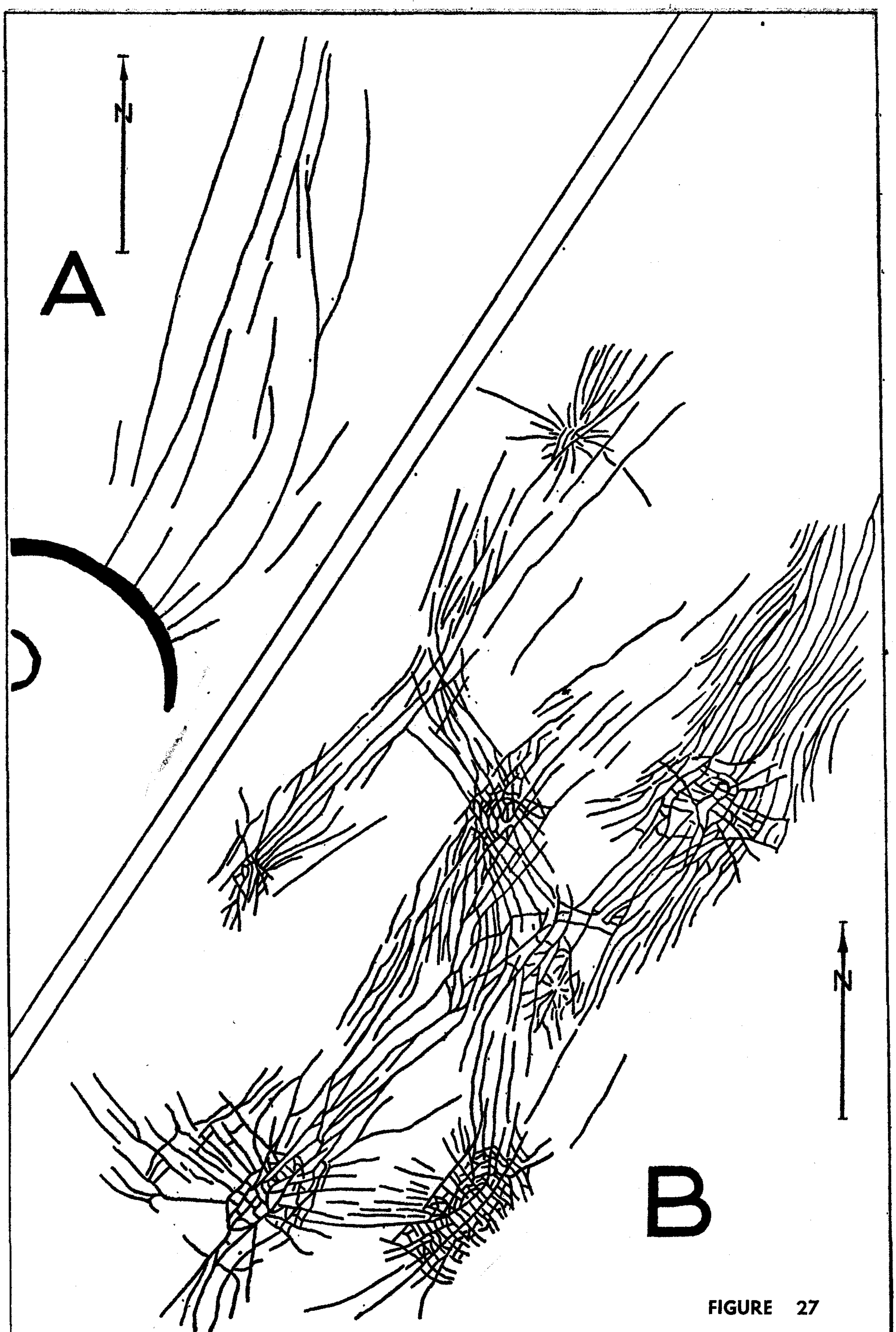


Figure 27. Surface cracking associated with duplicate corrugations. A—Cracks in massive riebeckite curving into a macule on the top surface of MB3 at 310 feet in Dales Gorge. The outer part of the macule represents the edge of a shallow disc-like depression. B—Cracking on a chert surface in b.i.f. 2, about 54 inches above the top of the 2nd 'shale' at Yampire Gorge. Note the tortoise-shell pattern over small macules below. Both sketches are traced from vertical photographs, and the north point on each is 6 inches long.

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FIGURE 28

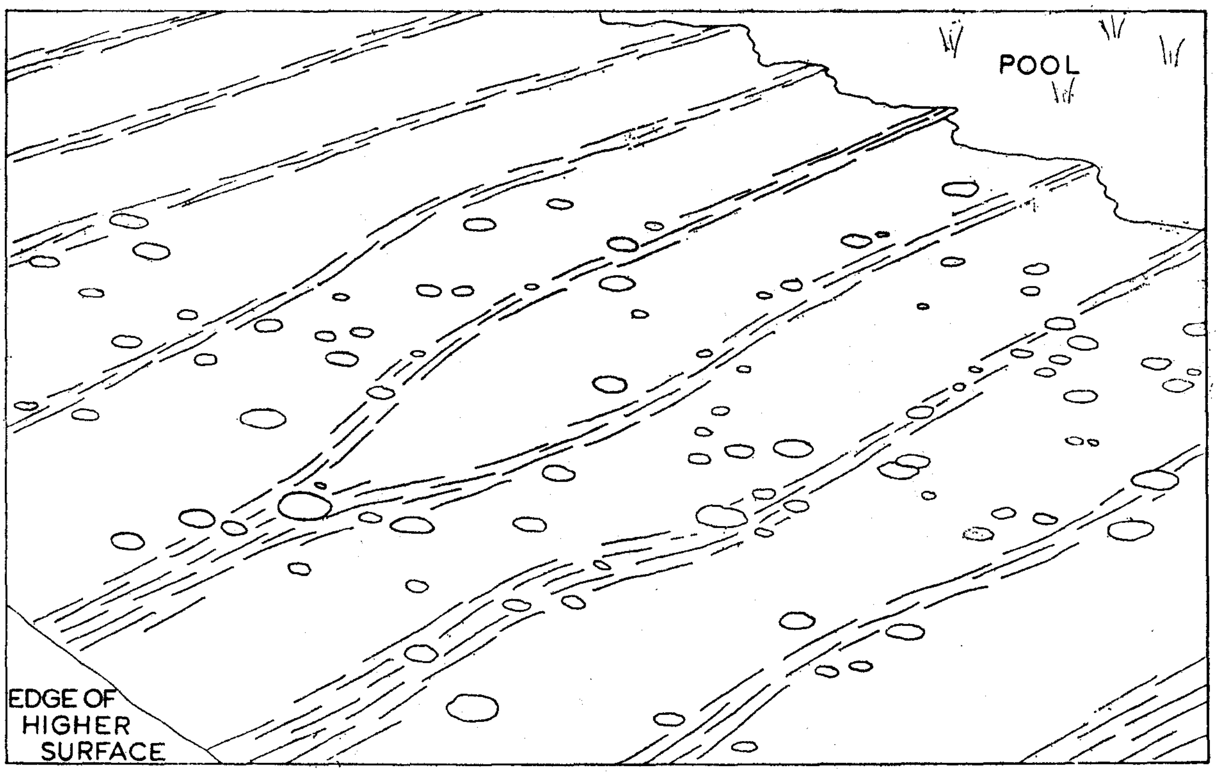


Figure 28. Sketch (traced from photograph) of smooth top surface of MB3 in the floor of Dales Gorge at about 400 to 430 feet. The observer is looking southwards, obliquely downstream across the gorge, over riebeckite swells with macules. The dashed ornament is diagrammatic and shows the exposed blue crests of the swells, which are about 5 feet apart. Note the bifurcation and the macules distributed over both swells and the intervening areas. Note also the projection of swells into the pool to give a saw-tooth effect. More distant macules, not easily distinguishable in the photograph, are omitted.

riebeckite in swells or macules, or is completely free of riebeckite. MB4 has duplicate corrugations but is of even thickness. It is the least riebeckite-prone of all the maculate bands, the chert just above it being marginally more susceptible; it has already been noted that this band is weakly maculate. These variations are discussed in the next section.

Crocidolite. As shown on Plate 40, crocidolite occurs at three levels within the maculate bands: below MB2, and both above and below MB3. No fibre lies in the Wittenoom lower seam, between MB1 and MB2, although it is possible that the fibre just below MB2 was mined as part of the lower seam at the old Wittenoom mine (Plate 34). The crocidolite associated with MB2 varies antipathetically with riebeckite, both on the scale of the riebeckite swells, over which it is invariably absent, and on a larger scale. It is absent at 1,400 feet where there is most crocidolite, increases westwards to an inter-swell maximum of 3 inches (2½ above, ½ below) at 1,000 feet, and by 600 feet is down to 1½ inches. The fibre below MB2 occurs only at 200 to 300 feet. It is similarly restricted to positions between swells, and has a maximum length of ⅜-inch. In some places there is a slight offset of crocidolite lenses, westwards above and eastwards below MB3, in sympathy with the trend of the crestal planes of duplicate corrugations at higher levels. Macules distort, but do not inhibit, fibre growth; crocidolite in many places runs right over the steep tops of macules which lie in appropriate relationship to the swells.

A REASSESSMENT OF THE DALES GORGE MEMBER AT WITTENOOM AND YAMPIRE GORGES IN THE LIGHT OF THE STRUCTURES AT DALES GORGE

Since the significance of much that is visible at Dales Gorge could easily be overlooked were it not for the excellence of the exposure, I made a brief re-examination of some localities in the Wittenoom and Yampire Gorge areas to check the extent of the Dales Gorge structures (for localities see Plate 35, D).

Yampire Gorge

The mill and main adit of the old mine at Yampire Gorge (Plate 35, D) lie at the north and south corners respectively of a small branch gorge (No. 2 Branch Gorge of Finucane, 1939, Plate 2) off the eastern side of the main gorge. They were connected across this by a railway bridge whose abutments still (1965) stand. The top of the first 'shale' is just visible on the south side of the branch gorge about 20 yards downstream from the bridge. Above it a continuous section may be followed upwards through MB1 to MB2, the top surface of which is exposed in the creek bed exactly beneath and a few yards up from the bridge. There are about 1.5 inches of fibre here in the Wittenoom lower seam, between MB1 and MB2. MB2 is maculate, and thickens and thins (3½ to 4½ inches, once only in the limited area of exposure) along an axis bearing approximately 035°. Minor rippling in the thinner parts follows this direction. It bears no riebeckite.

For several feet above MB2 at this locality the section is hidden by debris from the bench cut throughout this part of Yampire Gorge at about the level of the top of the Wittenoom upper mined seam. The cliffs backing these benches give excellent exposures of b.i.f.2, particularly the lower and middle parts. The following conclusions summarise observations on these cliffs within 400 yards of the bridge:

1. Duplicate structure is clearly discernible by repetition of similarly shaped cross-podded structures. It resembles duplicate structure at Dales Gorge in that: (i) it follows about the same axial trend very consistently, but on a bearing of about 040°; (ii) the internal slope of the cross-podded structures is consistently from southeast to northwest. It differs from that at Dales Gorge in that: (i) consecutive horizontal duplication intervals commonly depart up to 20% from the mean; (ii) the mean interval differs widely within small vertical distances; (iii) all measured intervals (means 66.7 to 98.5 inches) are higher than the very constant interval close to 60 inches of Dales Gorge; (iv) no

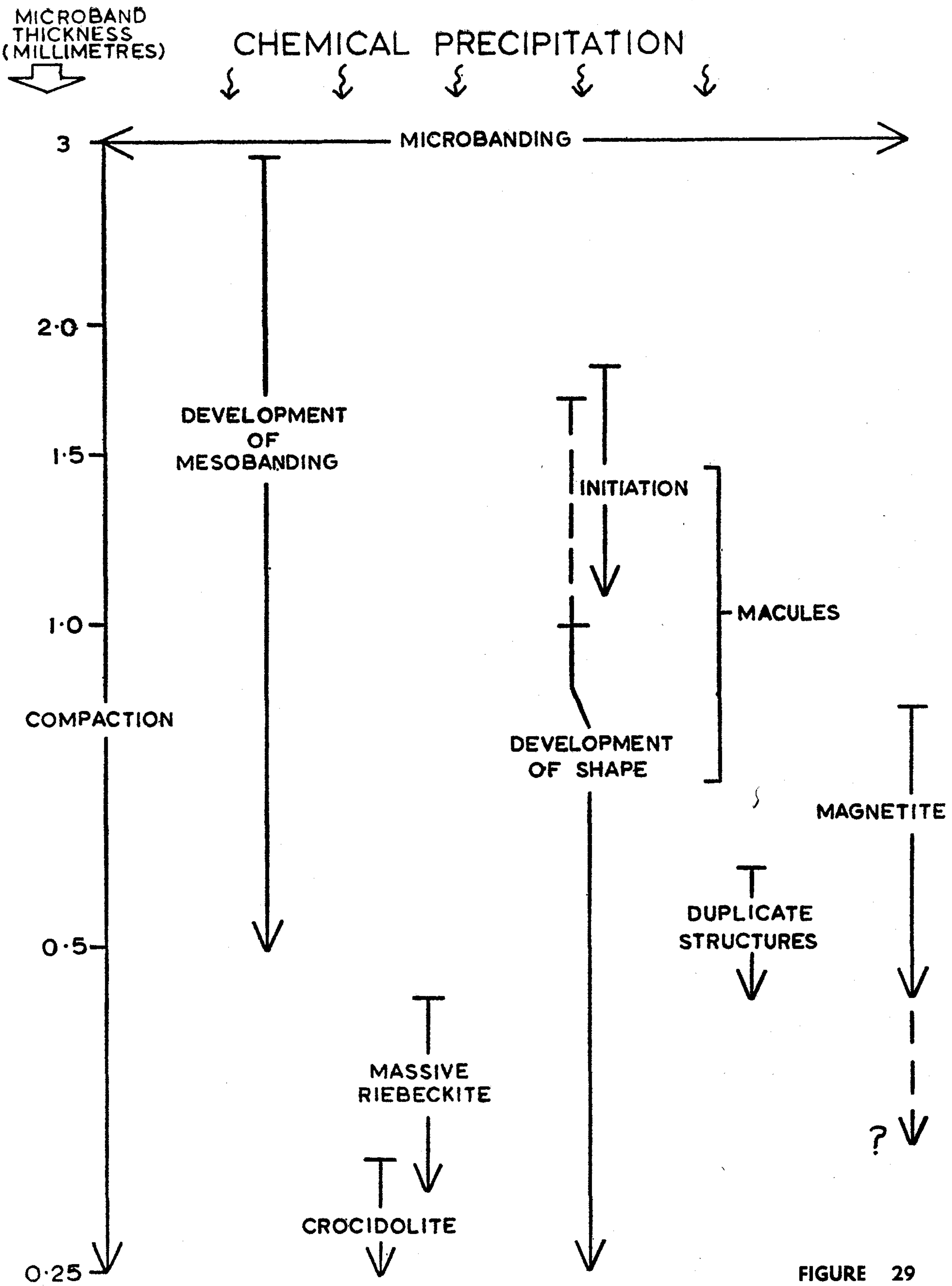


FIGURE 29

Figure 29. Diagrammatic summary of the inter-relationship of compaction, mesobanding, macules, magnetite, duplicate structures, riebeckite and crocidolite. The diagram represents a vertical section through a body of banded iron formation during its accumulation. The sediment-water interface is represented by the line marked microbanding at the top of the diagram. Three principal and partly independent factors increase together below this line: time, depth and compaction. The relationship between time and depth is controlled by rate of deposition and compaction. Slow deposition and high compaction could give the same depth-time relationship as rapid deposition and slow compaction. The relationship between compaction and both the first two factors depends on sediment response to pressure. It is not yet possible to make any estimate for depth or time scales, but compaction as indicated by microband thickness can be related to several structures studied at Dales Gorge; it is therefore used as an arbitrary reference standard at the left-hand side of the diagram. See text *(Compaction)* for further discussion of this scale.

duplicate corrugation is apparent. The total effect of these differences is that there is no total duplication of structural pattern as in Plate 39.

2. Duplication is expressed in length of crocidolite fibre in the crocidolite mesobands immediately adjacent to the thick massive riebeckite forming the roof of the old adits. In the fibre below this riebeckite the crocidolite varies between ½-inch and 2 inches, with the same slightly erratic variation noted for the duplication of cross-podding, and with the same axial trend.

Wittenoom Gorge

At Wittenoom Gorge 2 miles upstream from the (1965) A.B.A. administrative offices at the base of the cliffs on the eastern side of the gorge, just upstream from a deep permanent pool, cross-podding ridges are well exposed on a surface about 12 feet below the 14th 'shale'. They have the same internal slope as those of Dales and Yampire Gorges, and run at 045°.

Along the first 2,000 feet of the main adit of the Colonial mine at Wittenoom, cross-podding ridges are well exposed in the roof, and run sinuously in a southwest to northeast direction. In No. 5 haulage drive cross-podded structures show the same northwesterly internal slope. Although I had no time to clean the walls sufficiently to be certain, there appeared to me to be an irregularity of duplication interval similar to that at Yampire Gorge. All exposures examined in the Colonial mine were below the 1st 'shale'.

Mr. B. Chapple informs me that during his examination of cliff exposures in Wittenoom Gorge he has been able to detect the existence of small-scale variation in fibre content of the upper mined seam which is related to a regular arrangement of overlying riebeckite pods running in a northeasterly direction.

In the Wittenoom area all the rocks are more strongly affected by the regional folding than at either Yampire or, especially, Dales Gorge. It may well be that some of the minor structures associated with the duplicate structural trend are completely masked by the strong regional rippling.

Summary

From these scattered and incomplete observations it is clear that an approximately southwest to northeast direction, most clearly defined by cross-podded structures with a consistent internal structural sense, is an areally extensive feature of a considerable stratigraphic thickness of the Dales Gorge Member. It is an important small-scale control of crocidolite growth. It may be noted here that, of the three localities studied, Yampire and Wittenoom both have fibre in the upper mined seam of either economic or almost economic grade and also have irregular duplicate structures. At Dales Gorge, where the duplicate structures have spectacular regularity, crocidolite is virtually absent from this stratigraphic level.

DISCUSSION OF THE INTER-RELATIONSHIP OF COMPACTION, MESOBANDING, MACULES, MAGNETITE, DUPLICATE STRUCTURES, RIEBECKITE, AND CROCIDOLITE.

It is artificial to discuss the inter-relationship of several related factors under exclusive headings, since the relationship between X, Y and Z is as relevant for X as for Y or Z. This should be understood throughout the section, where for clarity those points which seem particularly relevant to one feature are arbitrarily grouped under that heading. However, Figure 29, a graphic summary of the relationships described, is intended to show the coherence of the arguments in spite of the artificiality of the headed subdivisions. This discussion embraces conclusions both from evidence presented earlier in this report and also from other evidence not yet published.

The basic hypothesis

It was proposed previously (Trendall, 1965, p. 63-64) that the mesobanding of banded iron formation was formed by diagenetic modification of a probably colloidal chemical precipitate in which microbanding, reflecting seasonal variations of the deposited material, was the only primary structure. Thus it was supposed that microbanding was originally comparatively coarse, and that by gradual compression and compaction the parent material changed to primitive chert, to flat-modified chert, to QIO and possibly to magnetite, variations of response at different levels giving the present mesobanding. During this process the increasing fineness of the microbanding, observable or deducible, was proposed as an index of the degree of compaction. This hypothesis has since received such strong chemical support, which it is hoped to publish elsewhere, that it now seems proper to apply it as a main basis for the further analysis of the several inter-related diagenetic factors which are the subject of this discussion.

Compaction

It is thus assumed that the microband thickness is an index of the degree of compaction of a mesoband; the compaction of a stratigraphic thickness of several feet is harder to express precisely, since the many different mesobands will have different degrees of compaction. In Figure 29, the microband thickness of thick flat-modified cherts has, for the purposes of the diagram, been chosen as an index of the local degree of compaction. It should be understood that this scale is not related to time in that the number of microbands (= years) between any two marked microband thicknesses is not shown. However, the scale has been shown logarithmically on the assumption that equal increments of pressure will cause equal percentage decreases of volume. The diagram therefore probably shows depth relationships more truly than with a purely linear compaction scale, even though absolute depths are not indicated.

Mesobanding

By 'development' of mesobanding in Figure 29, is meant the final definition of all mesoband boundaries in the rock; it does not mean the acquisition by each mesoband of its final state or thickness. The actual mechanism of mesoband development is still a major difficulty in applying the basic hypothesis, since it requires the extraction of very large quantities of material vertically out of the iron formation, across the microbanding but not obliterating it. For this reason it is assumed that the definition of mesobanding began very soon after deposition. There are two arguments for the lower limit of mesoband development: it was *not* complete before the duplicate structures (see *Duplicate structures* below), and it was probably completed before riebeckite growth, since there is no instance known to me of riebeckite-free mesobanding represented laterally by massive riebeckite in which the former course of equivalent mesobands cannot be detected.

Duplicate structures

I have been unable to find, as a guide to their interpretation, a close comparison in geology for the extraordinarily repetitive regularity of these structures, the full extent of which is not yet known. Cilliers and Genis (in press) have described, from the probably coeval asbestos-bearing iron formations of South Africa, "contemporaneous folding", . . . "even in areas where regional folding is practically absent", which they believe to be "the result of both flowage of the material soon after deposition and subsequent contortion of individual layers during crystallisation of the colloidal material". Their illustration (ibid., fig. 3) of such "gypsum folding" shows characteristics comparable with the duplicate corrugations of Dales Gorge. It is repetitive, although lacking the nearly perfect duplication of Dales Gorge, and has inclined crestal planes, with limbs differing slightly in thickness. On the other hand it has wavelengths of about 1 to 2 inches, an amplitude of about ½-inch, and much wider shape variation in successive bands.

Although Halligan and Daniels (1964) have noted a late (Rocklean) fold trend in the Ashburton area with the same general trend as the duplicate structures at Dales Gorge, Wittenoom Gorge and Yampire Gorge, it seems unlikely that these structures are in the normal sense tectonic; and it is virtually certain that they were not formed after the main east-west regional (Ophthalmian) folding, since they maintain their trend over a large area which is slightly but definitely affected by this. The small open folds (Plate 35, B) whose axes are parallel to those of the duplicate structures in Dales Gorge may indeed be related to Rocklean movement, although there is a suggestion (see *Riebeckite*, below) that they control riebeckite distribution. At present their status is uncertain.

Better evidence for the time relationship of these structures comes from cross-podding. The presence of *additional* pod cherts in cross-podded structures (Figure 26) shows that they formed before the full development of mesobanding, while their general definition by and corrugation of mesobanding indicates that they formed at a late stage of its development. The presence of pyrite along crests of swells also shows that they formed before the close of potential internal rearrangement of material by water.

It seems possible that the duplicate corrugations of Dales Gorge result from gentle mass slumping from east-southeast to north-northwest down the bottom slope of the depositional basin. Ryan and Blockley (1965) have independently shown that this is compatible with the possible shape of the basin deduced from isopachs of the Dales Gorge Member. The structures probably formed quite rapidly at a stage when the rock was not quite rigid enough to resist the downslope component of a very great weight of overlying sediments.

Macules

Although macules resemble closely in surface expression such structures as sand volcanoes (Gill and Kuenen, 1958) and gas evasion structures (Cloud, 1961) the invariable continuity of microbanding above, below, and through them contrasts strongly with the internal structures of these (Gill and Kuenen, 1958, plate 36-1; Cloud, 1961) and precludes any possibility that they acted as channels for the transfer of material. The symmetry of upper and lower parts of many macules is another clear structural distinction from superficially similar structures.

The areal distribution of macules is not related to duplicate structures. Duplicate corrugations are such an important and penetrative structural feature of the rock that, if macules formed after them, macule distribution would surely be controlled by them. Duplicate structures formed before the complete stabilisation of mesobanding. On the other hand, macules formed well after the first definition of mesobanding, since they usually are confined within limits defined by it. Macules thus formed during development of the mesobanding: a time of compaction on a massive scale. The interpretation of the coarsely microbanded cores as volumes of otherwise normal chert which failed to compress during compaction of the enclosing material seems more reasonable than any explanation involving swelling of the macules from a previously smaller state. There appear to me to be no features of macule structure which are not thus explicable. The varieties of surface expression already described are easily attributable to the differing responses of the adjacent material in accommodating the different relative volume changes over differently shaped resistant cores.

The problem remains of explaining the resistance to compaction of macule cores. The relationship of pod cherts and QIO has already been described (Trendall, 1965, p. 63). Chert pods resemble macule cores in that they are restricted volumes of parent material which have remained comparatively unaltered, and comparatively coarsely microbanded, during compaction of the surrounding material. Apatite is conspicuous in all thin-sections of macules so far examined. A composite analysis (unpublished) of pod chert shows 0.45% P_2O_5; a similar sample of the adjacent QIO has 0.09 % P_2O_5, while a composite sample from various holes of a single flat-modified chert has 0.05% P_2O_5. It may be that phosphate aggregation is a controlling factor in resistance to compaction, and that macules are essentially phosphate nodules.

Phosphate nodules are common in Phanerozoic rocks (Pettijohn, 1957, p. 473-4), and have also been described in the Precambrian (Geijer, 1962; Peach and others, 1907). In those described by Peach and others (p. 288) from Torridonian shale "the laminations of the rock can be distinctly traced into the (phosphatic) lenticle, but the laminae are further apart in the lenticle than they are in the shale, thus proving that there has been greater compression in those portions of the rock which have not been cemented by phosphate." The comparison with Brockman Iron Formation chert pods seems close, although here it must be assumed that a very small amount of phosphate critically affects the compressibility; for macules the core shape is an important difference. Hill (1948) has described vertical hollow cylindrical (= pipe-like) limonite structures in sand which are probably concretionary, but there seem to be no close comparisons among concretions for the bowl shapes of macule cores. Nevertheless, the most acceptable hypothesis at present seems to be that macules are formed by compaction around concretions.

There are in the Brockman Iron Formation a variety of smaller poddy structures down to spheroidal pea-like forms in dark QIO, of which no description has yet been published. It is not unlikely that these, together with the supposedly algal *Collenia brockmani* Edgell (1964), for whose organic origin no conclusive evidence has been presented, and the concentrically ridged pseudofossils (Edgell, 1964, Plate 3; Halligan and Daniels, 1964, Plate 24, figure 1) are related structures.

If macules are concretionary their development may be considered in two stages: the initial aggregation of phosphate, and the development of shape. Clearly the development of shape continued until the end of compaction. Its beginning is shown for each macule, assuming *no* later core compaction, by the microband thickness of the core, which in the examples illustrated (Plates 37 and 38) varies between 1.0 and 1.7 mm. If it be supposed (see *Mesobanding*, above) that modification of the present material began early, on a large scale, then it must be supposed that the aggregation of phosphate which initiated the macules took place quickly, since the cores are often sharply defined. In Figure 29, this is shown by the slight offset of macule initiation and shape development. A low position of macule initiation in the gap between mesoband development and macule shape development is in accord with the necessity for clear mesoband definition before macule initiation.

Riebeckite

It has been necessary to deal with macules at some length in this report since the conspicuous association of maculate bands with riebeckite at Dales Gorge suggests close genetic connection of the two. In fact the absence of riebeckite from MB2 at Yampire, where it pinches and swells and has macules just as in the invariably riebeckitic MB2 of Dales Gorge (Plate 40), shows that reibeckite is later than either macules or duplicate structures. The same conclusion follows from the obvious close control of riebeckite distribution by duplicate structures, well shown by MB3 in Plate 40. Riebeckite is not necessary for the formation of either duplicate structures or macules, but both control its subsequent growth, and it appears that riebeckite replacement is impossible, or at least, less easy, beyond a certain point of chert compaction.

In general it is clear from Plate 40 that the lateral variation of riebeckite in all four maculate bands is sympathetic, with a maximum at about 1,400 to 1,500 feet, a minimum at 900 feet and a probable second maximum at 300 to 400 feet. Comparison of Plates 35, B and 40 shows that some correlation may exist between the small open folds dipping south-southwest and riebeckite concentration. The maximum at 300 to 400 feet corresponds to the axis of a syncline; the minimum at 900 feet is close to the crest of an anticline; and the maximum at 1,400 to 1,500 feet corresponds with a sharp irregularity of the folding. The correspondence may be coincidental, especially so since at present the areal shape of riebeckite concentration is not known. This could easily have an elongation oblique to the axial trend of the folds.

Magnetite

It was noted before that magnetite is a diagenetic, not a primary, mineral in the Brockman Iron Formation (Trendall, 1965, p. 63); this also appears to be true of the Lake Superior iron formations (La Berge, 1964). The filling by magnetite of cracks developed during the compression of macules, and its probable association with the cracks in duplicate corrugations indicates the overlap of all these features. It is likely that magnetite began to form a good deal earlier than duplicate structures, since it plays a large part in the definition of mesobanding. A lower limit of magnetite formation is suggested by its texture in association with crocidolite (Trueman, 1963). Here it clearly played an entirely passive part during crocidolite growth. In massive riebeckite mesobands I have seen textural evidence neither for the growth of magnetite later than riebeckite nor for the direct replacement of magnetite by riebeckite. Although fuller evidence for magnetite-riebeckite relationships is to be given elsewhere, it may be useful here to summarise what appear to be the most likely conclusions: magnetite began to crystallise before riebeckite, whether or not soda was available; when temperature and pressure were high enough riebeckite formed whereever soda was available, but magnetite already formed was not normally redissolved; however, if soda was not available magnetite probably continued to grow. In effect, it seems that the growth of magnetite fixed iron into chemical stability.

Crocidolite

There is strong textural evidence from those crocidolite mesobands adjacent to massive riebeckite that the growth of crocidolite was later than the massive riebeckite. Although there is no evidence for the relative age of crocidolite mesobands remote from massive riebeckite, it seems reasonable at present to suppose that all crocidolite formed together, and it has therefore been shown after riebeckite in Figure 29. Although crocidolite is controlled by duplicate structures there seems no reason to suppose that the two were at any time forming together. From Plate 40 it appears that the simple hypothesis noted earlier of riebeckite and crocidolite relationship may be partly true, although the relationship is not accurately quantitative; there may be a question here of excessive growth of massive riebeckite affecting speed of crocidolite growth by lowering soda concentration, rather than by removing soda completely.

Final synthesis

Ryan and Blockley's (1965) regional field studies have shown that crocidolite may be concentrated in an area away from the deepest part of the depositional basin of the Dales Gorge Member. It may be useful finally to outline a hypothesis relating this to the preceding discussion. Suppose a flat basement surface to be gently, steadily and symmetrically warped to create and maintain a sinking basin with surface conditions such that chemical precipitation takes place, and suppose the rate of precipitation to be proportional to the depth of water. The basin would then have a cross-section like that of the top part of Figure 30. If the isotherms had originally been parallel to the surface it may be supposed that they would tend to resume this attitude during depression, and that isotherms within the sedimentary body would be

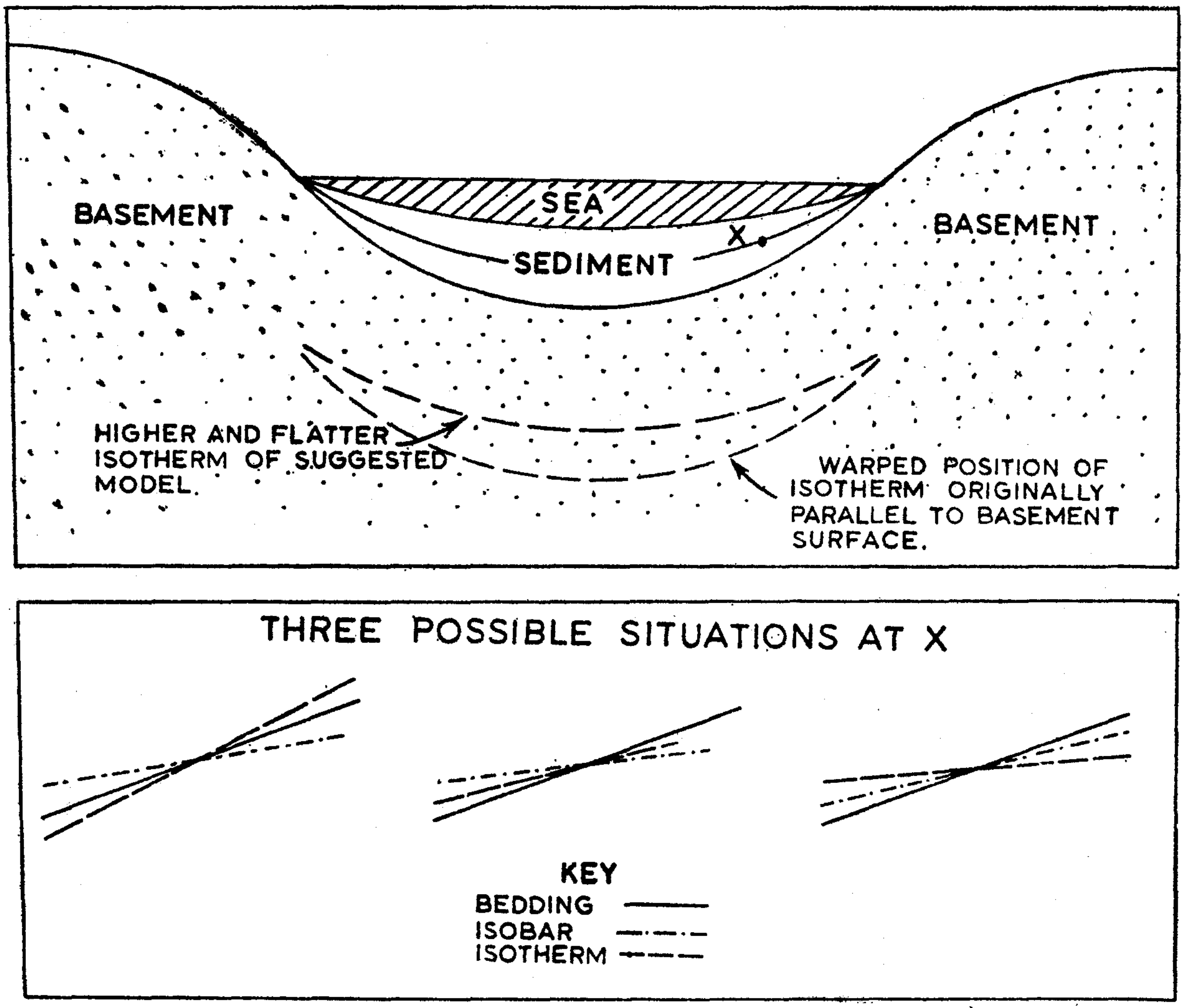
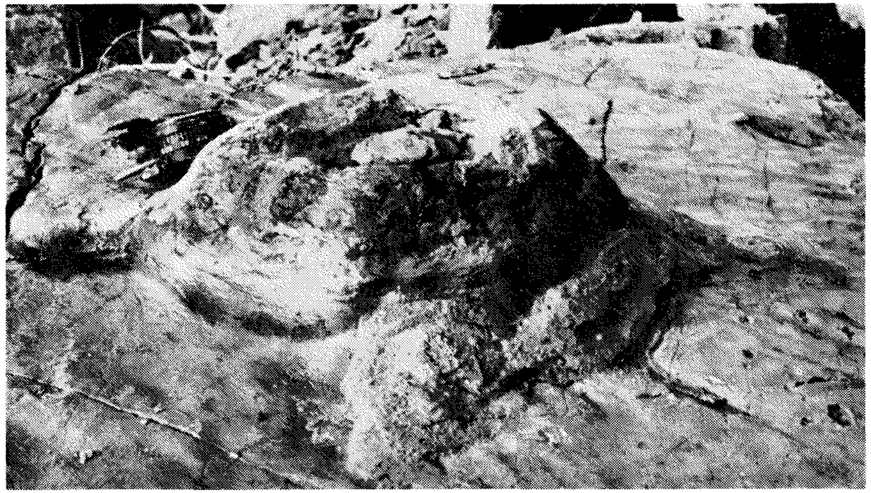


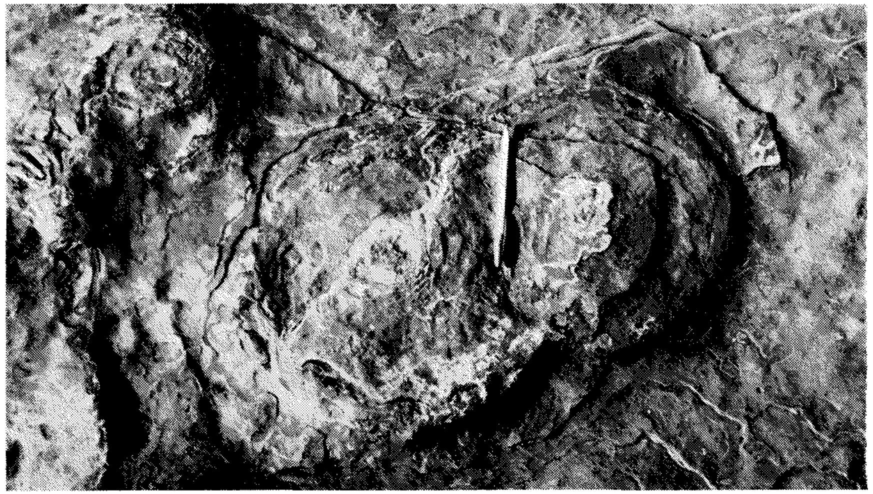
FIGURE 30

Figure 30. Diagrams illustrating possible pressure-temperature-bedding relationships in a symmetrically sinking basin. Vertical scale and slopes are very greatly exaggerated. See text for further explanation and discussion.

A—Volcano-like form with radial furrows on the upper surface of MB4 in Dales Gorge at 680 feet, on the north-east side of the gorge. The pencil is 6 inches long and points north.



B—Form with central depression encircling an internal boss. Compare Plate 38, A. This example is from Yampire Gorge on a fallen block of uncertain stratigraphic position; by comparison with others *in situ* nearby it is almost certainly an upper surface. The case of the compass is almost an inch high.



C—Two overlapping discoid forms in Dales Gorge at 190 feet on the top of MB2. Most of the material is massive riebeckite, with coarse (average grain diameter about 4 mm) quartz in the central columns. The pen is 6 inches long and points 020°.

D—Looking in a direction 200° over the top surface of MB1 at 700 feet in Dales Gorge, showing an even distribution and density of macules. Five feet of tape is pulled out from the reel.

Plate 37. Cut and smoothed vertical median sections of macules. The double-ended arrow by each photograph represents a length of 5 cm. The numbers represent the mean microband width in millimetres over the thickness marked by the adjacent black lines.

A—The simplest form of macule, from MB4 in Dales Gorge. A central column with an axis in this example inclined at about 17° from the vertical, has clear internal microbanding twice as thick as that of the more compressed chert. The darkness is due to riebeckite replacement.

B—Structure transected at 483 feet 2 to 9 inches in Hole No. 51 of the A. B. A. Co. Wittenoom drilling; this is a stratigraphic level in the lower part of b.i.f. 6. By comparison with C it is evidently the edge of a macule. Note the magnetite-filled cracks obliquely crossing the microbanding.

C—Macule from boulder at Yampire Gorge showing most resistance to compaction by a thick tube with internal irregularity of response. The top and bottom of this example are not known for certain, but are likely to be as shown by comparison with others locally *in situ*.

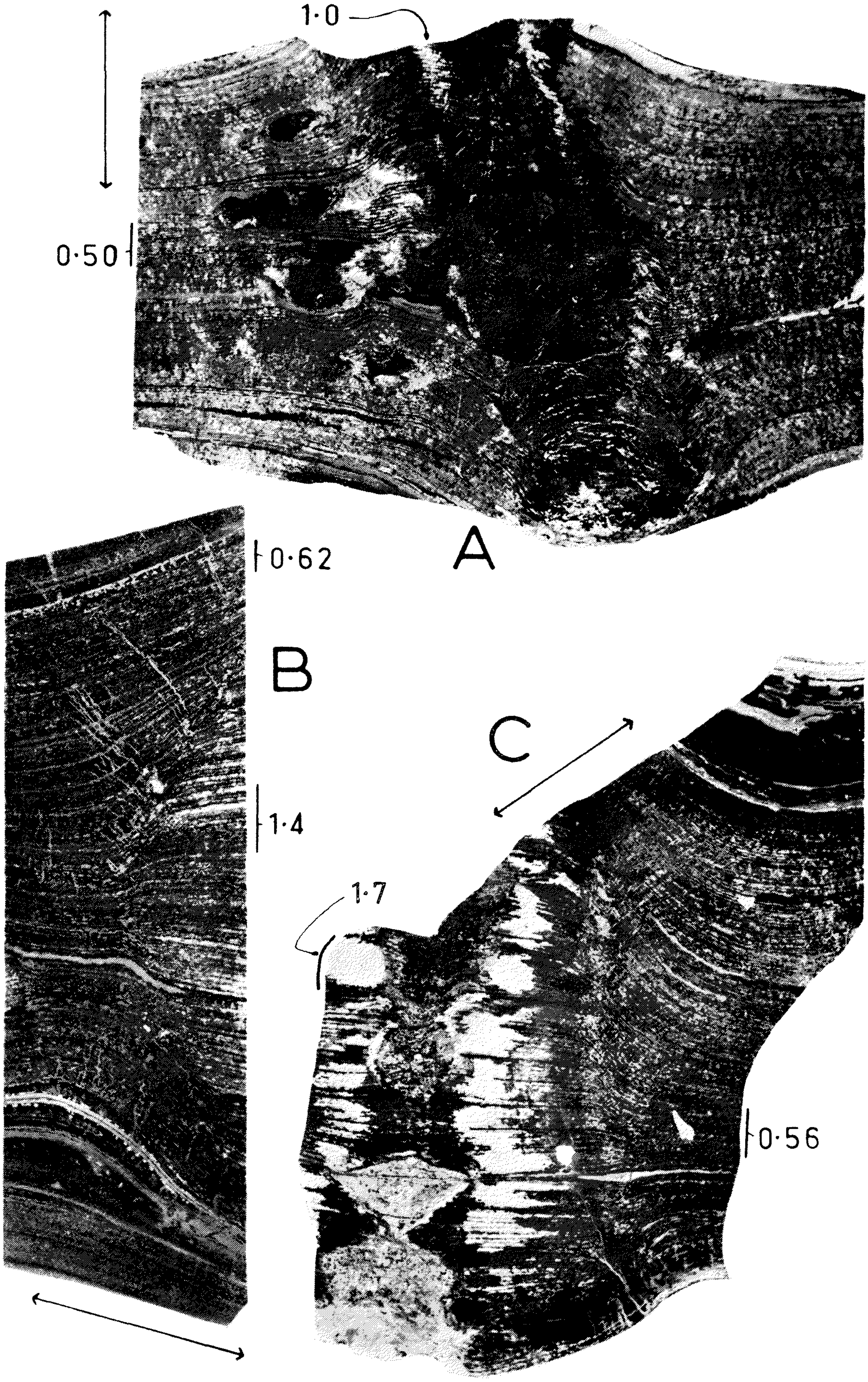

1·0
0·50
A
0·62
B
1·4
C
1·7
0·56

Plate 38. Cut and smoothed vertical median sections of macules. The double-ended arrow by each photograph represents a length of 5 cm. The numbers represent the mean microband width in millimetres over the thicknesses marked by the adjacent black lines.

A—Macule from boulder at Yampire Gorge, showing most resistance to compaction by a central core resembling a squat thick-walled bowl, with an interior into which the (supposed) upper part has been squeezed to give a summit depression encircling a central boss, as in Plate 36, B (which is a different macule).

B—The lower part of a macule from MB3 at 110 feet in Dales Gorge. As in Plate 37, C, the least compression is in a pipe-like volume (with microband width 1.4 mm), here surrounding a central cylinder of coarse quartz in which the microbanding is defined by minor riebeckite. On rough broken surfaces of this quartz no microbanding is visible. The darkening to the left hand side, and in the central cylinder, is due to riebeckite replacement. Note the irregular cracking in the lower part; the veining material is mainly cherty quartz darkened by a comparatively small riebeckite content.

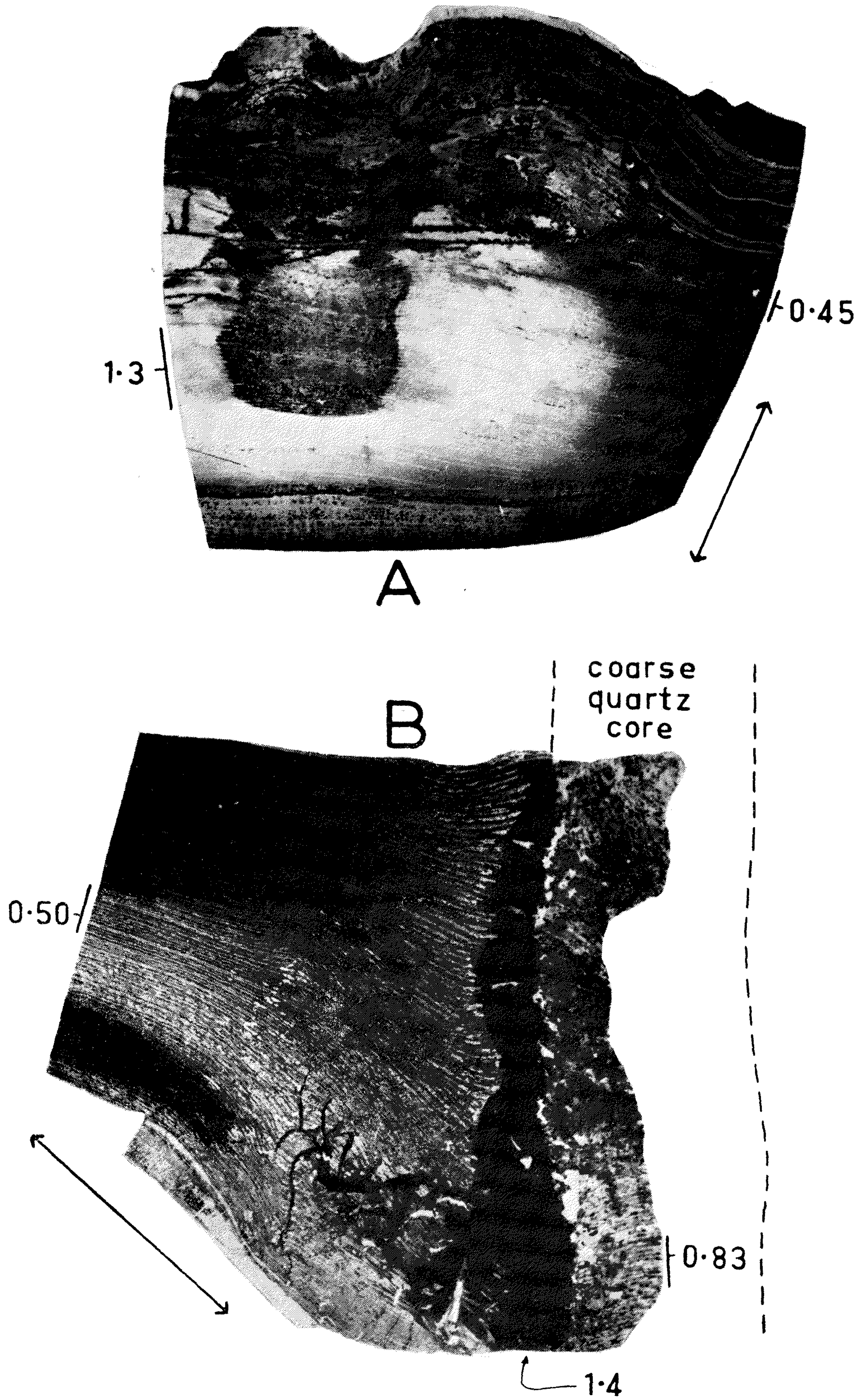
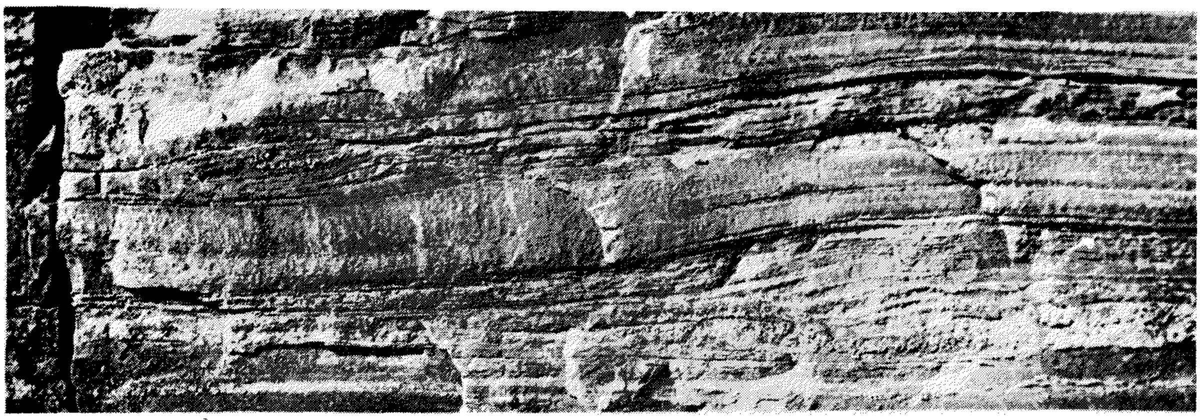

1·3
0·45
A
B
coarse
quartz
core
0·50
0·83
1·4

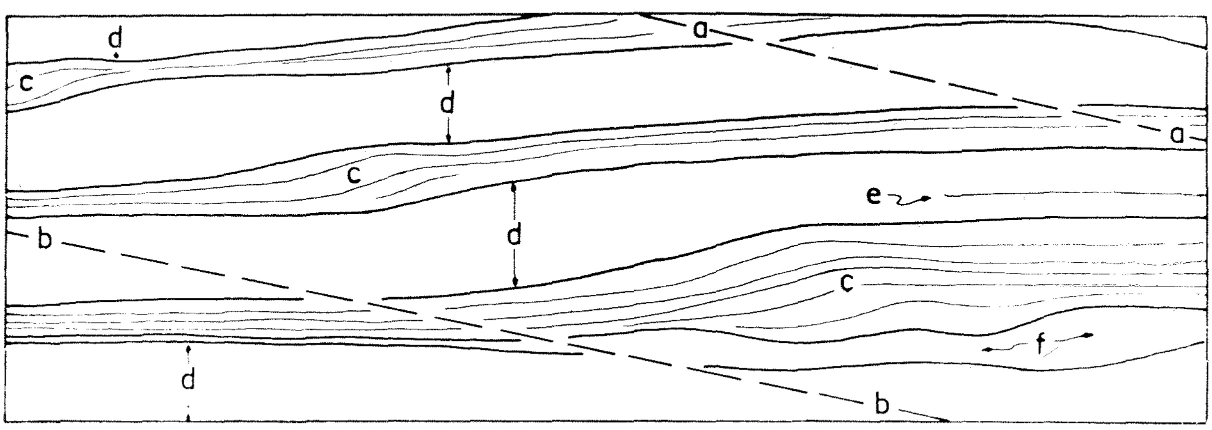
Plate 39. Equivalent parts of the opened limbs of duplicate corrugations at Dales Gorge (see Figure 25). The area shown in each figure is about 7 inches high and 21 inches wide, at a stratigraphic level between 56 and 63 inches above the top of MB4. A, B and C are at approximately 340, 345 and 360 feet, looking 020° at a vertical joint face on the north side of the gorge; thus A and B are from adjacent corrugations, while two duplications between A and B are not shown. About 350 similarly indistinguishable photographs could be taken at intervals of 5 feet up and down the remainder of the 1,800-foot length of Dales Gorge studied. In D the salient features of A, B and C are shown diagrammatically: a-a = crestal plane of corrugations, dipping easterly; b-b = trough plane; c, c, c = cross-podded structures, occurring in groups of alternating thin (primitive) chert and QIO mesobands; d, d, d = thick flat-modified chert mesobands. The alternation of thick flat-modified cherts with groups of thin primitive cherts in QIO is typical of the whole of b.i.f. 1. Note the perfection of duplication in detail. For example: e = a parting in a flat-modified chert which in each of A, B and C decreases in development from right to left; f = a QIO mesoband thinning from right to left and showing exact duplication of shape beneath the cross-podded structure (the pale granular appearance in the photographs is due to the adherence of coarse quartz to the QIO on the joint face).

A



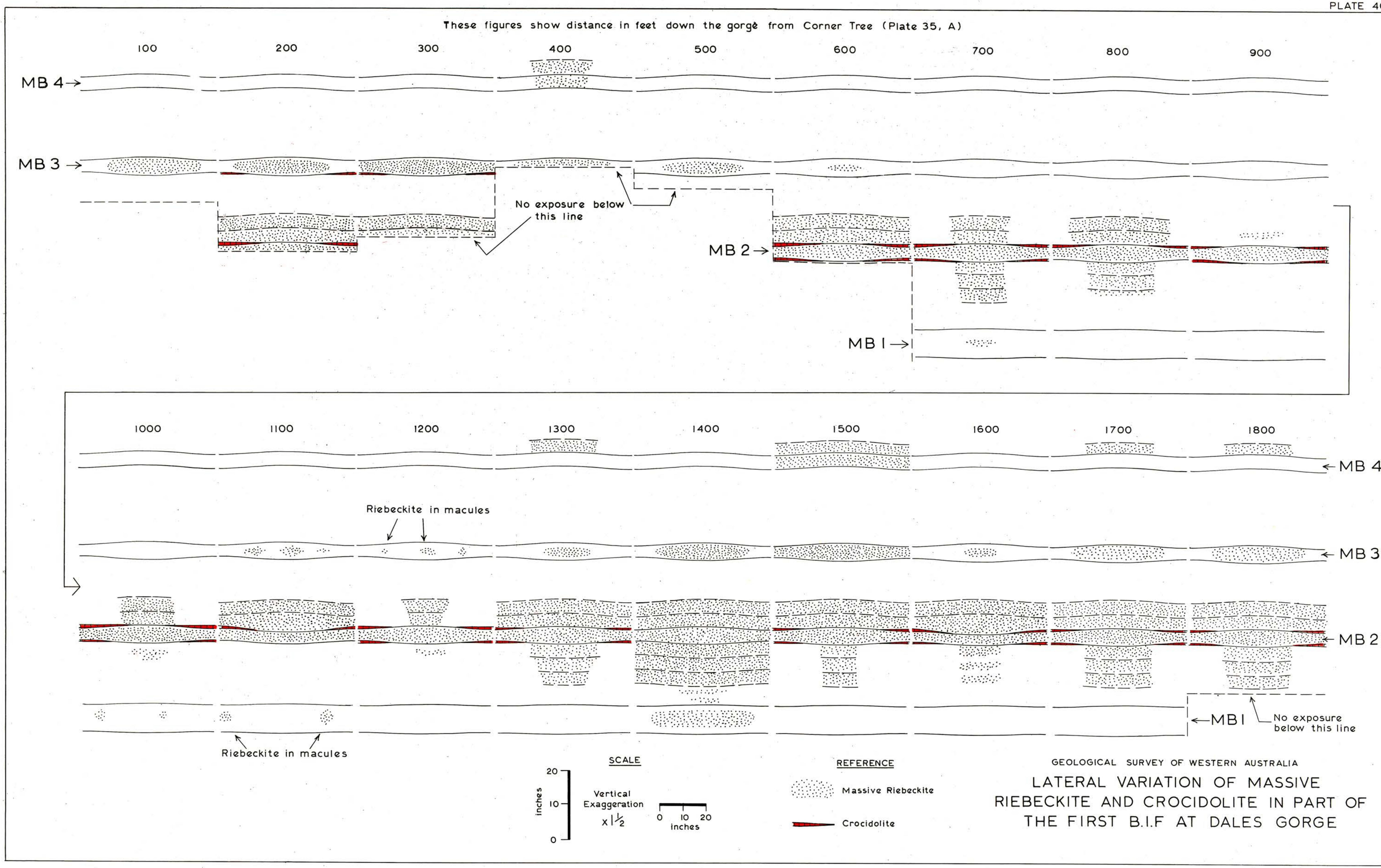
B

C



D

PLATE 40



GEOLOGICAL SURVEY OF WESTERN AUSTRALIA

LATERAL VARIATION OF MASSIVE RIEBECKITE AND CROCIDOLITE IN PART OF THE FIRST B.I.F AT DALES GORGE

9241

flatter than the basin floor. Since at any point towards the side of the basin (X in Figure 30) the pressure is greater, at any constant stratigraphic level, nearer the centre of the basin the isobars must dip less steeply than the bedding.

At X there are thus, some time after deposition, three possible relationships of bedding, isobars and isotherms. The relative speeds of sinking and deposition and the physical properties of the sediment will jointly determine which of the three situations of the lower part of Figure 30 will prevail. In either the left-hand or the central situation a point at the same stratigraphic level as X nearer the basin centre will reach a given pressure at a lower temperature than X. It may then be supposed that soda-bearing water was expelled before conditions for riebeckite growth were reached. In the situation on the right-hand side a stratigraphic level nearer the basin centre than X will become hotter than X before it is subjected to the same pressure. Even with this incomplete exploration of a simple model it is clear that, with varying rates of deposition in a circular basin, the critical condition for riebeckite growth could be reached in rings of varying radii at different stratigraphic levels. It is essential in any attempt to use such models for planning asbestos exploration, to acquire more complete data on the exact shape of riebeckite and crocidolite enrichments than are yet available.

RELEVANCE OF THIS WORK FOR CROCIDOLITE EXPLORATION

It has been shown that, on a small scale, enrichment in riebeckite and crocidolite growth in the Dales Gorge Member are closely controlled by unusual minor structures (duplicate structures) which probably formed by late compactional response to the downslope component of the weight of later sediments. On a larger scale it is quite certain that the controls of riebeckite and crocidolite are not yet known with the confidence essential for use in an expensive blind drilling programme.

However, there is one immediate application of these results in any asbestos exploration or ore evaluation involving drilling. From Plate 40 it is clear that a single drill hole in the 900 to 1,300 feet area of Dales Gorge will stand about equal chances of showing 0 or 2 inches of fibre adjacent to MB2. Neither figure gives any idea of the distribution or total quantity of fibre at this level over a circle of, say, 50 feet around the hole. To obtain a meaningful result from a single deep hole here it would be necessary to wedge out at least twice along an east-southeast to west-northwest line, to give other samples over a total width equal to the duplicate wavelength (5 feet). Note that if duplicate control of fibre is ignored and wedging is carried out several times along, instead of across the duplicate structural axis, the first, possibly spurious, result will appear to receive good statistical confirmation.

This finding probably explains, at least in part, my own previous failure to find any consistent areal pattern of riebeckite enrichment in the drilling at Wittenoom. Clearly boreholes transecting the Dales Gorge section (Plate 40) at the crests of swells will show no fibre adjacent to MB3 but will range widely in massive riebeckite content. On the other hand, in boreholes passing between swells there would be a strong inverse relationship between riebeckite and crocidolite. But with random holes this correlation will be masked by the scatter given by the crestal holes, and interpretation with the confidence necessary for an economically useful hypothesis would be impossible.

ACKNOWLEDGMENTS

Thanks are due to the management and staff of the Australian Blue Asbestos Co. Ltd., in particular to the company geologist, Mr. Barry Chapple, for help of various kinds.

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DIVISION V

School of Mines, Western Australia Annual Report — 1965

The Under Secretary for Mines:

I have the honour to submit for the information of the Honourable the Minister for Mines my report for 1965. The report refers to Kalgoorlie and to Norseman.

KALGOORLIE

Enrolments

The number of students enrolled in 1965 was 275—a decrease of 54 by comparison with the previous year. This is the first time for many years that enrolments have dropped below 300 and it reffects the apparent lack of interest in the mining and in the metallurgical industries by the young people of Western Australia. This is, indeed unfortunate at a time when the industries urgently need trained men. This lack of interest is not restricted to Kalgoorlie, or Western Australia but is apparently world wide.

Table I gives the individual and class enrolments for 1965 and for the four previous years; Table II, the enrolments in the various subjects; and Table III the students enrolled for the various courses.

Revenue

The revenue for the year was £7,547 18s. 4d.. Table IV shows how the revenue was made up; and Table V the fees paid by students in the various age groups. The moneys received include £2,000 from the Chamber of Mines as a contribution to the Apparatus and Equipment Trust Fund.

Staff

The following staff changes occurred during the year:

Bartram, P. M.; Library Assistant; 2/11/65—Appointed.

Beardman, B. W.; Junior Clerk; 6/8/65—Transferred.

Caudwell, L. H.; Workshop Technician; 26/7/65—Appointed.

Cunneen, J. R.; Messenger; 5/7/65—Appointed.

Forrest, A.; Cadet; 26/11/65—Resigned.

King, J. C.; Cadet; 10/3/65—Appointed; 28/10/65—Resigned.

Murphy, J. M.; Junior Clerk; 13/9/65—Appointed.

Perkin, R. E.; Cadet (Norseman); 2/2/65—Appointed.

Renton, K. J.; Laboratory Assistant; 31/12/65 Resigned.

Rowe, E.; Typist; 29/10/65—Resigned.

Thomas, M. J.; Typist; 17/12/65—Resigned.

Treleven, R.; Messenger; 24/6/65—Resigned.

White, K. S.; Lecturer; 8/2/65—Appointed; 10/9/65—Resigned.

During the year efforts were made to fill the vacant positions in the Engineering Department and in the Metallurgical and Chemistry Department. These positions were widely advertised throughout Australia and in Great Britain. We were able to fill one position in Engineering Department and the appointee will start in February, 1966. The other positions are still vacant.

Courses of Study

No changes were made in the Courses.

Annual and Supplementary Examinations

The results of the Annual Examinations are summarized in Table VI and VII, which are based on class enrolments and on individual enrolments respectively. The figures are similar to those for previous years.

The results for individual subjects are given in Appendix I.

Scholarships and Prizes.

Two students held Mines Department Scholarships—L. J. Molloy, an Entrance Scholarship and D. G. Brioschi, a Senior Scholarship. Both students completed a satisfactory year's work.

Twelve students held Chamber of Mines Scholarships and all except one completed a satisfactory year's work. Two of these students—V.J. Absolon and W. S. Maley—completed the Associateship Courses for which they were enrolled.

The usual awards were made at the end of the year and details are given in Appendix 2.

L. M. Karczub, who held a Mines Department Scholarship during 1962 and 1963, was awarded and A.E.I. Overseas Fellowship and will leave for England early in 1966. Ten to twelve of these Fellowships are awarded to Australian students each year and for some years a student of the School has received a Fellowship. During 1966 there will be four School of Mines graduates holding Fellowships in England.

Diplomas and Certificates.

Details of the Diplomas and Certificates awarded in 1965 are given in Table VII. Fifteen students received Diplomas; 21, Certificates; and four completed Technician Courses. These numbers are less than those awarded in the previous year, but are still very satisfactory, and above those for 1962 and 1963.

The awards were presented by the Minister for Mines, the Honourable A. F. Griffith, at a function held in the Kalgoorlie Town Hall on Wednesday, May 26. In his address the Minister referred to the spectacular developments which had taken place in the mineral industry in W.A. since 1960 and to the reduced number of students entering the industry as shown by the enrolments at the School.

He went on to say that the School could not only train men for gold mining, but also for all types of mineral development.

The Guest Speaker was Dr. H. K. Worner, Director of New Process Development, Conzinc Rio Tinto of Australia Ltd., and the title of his address was the "Romance of Metal Winning in Australia." Dr. Worner referred to the activities of the early metal seekers in Australia and to the various periods of exploration. He showed the great contributions which the mining and metallurgical industries had made to the development of Australia. Towards the end of his address he referred to the need for trained men and, in particular, to this need in the mining and metallurgical industries. Dr. Worner illustrated his talk with slides showing diagrams and photographs. The President of the Students' Association, Mr. R. M. King, thanked the Minister and Dr. Worner for coming to Kalgoorlie and for the addresses.

Library.

Students have continued to use the reading room for study purposes, and there has also been consistent use of the school library service by the staff of mining companies. In the short time we were fortunate to have the services of a full time typist in the library we were able to bring some of our records up to date and also revise the subject catalogue. The issue of a list of subject headings for the school catalogue has helped in keeping material in the right place in the catalogue. The issue of Library Bulletins and Book Lists has been kept up to date and appreciation of the Bulletin is indicated by continued requests for further information on items listed.

The number of items catalogued during 1965 was 711—approximately the same as 1964, but a considerable increase over previous years.

There has also been an increase in the number of inter-library loans. Again, the School has lent more than it has received, and in only seven cases were we unable to supply the item asked for. A growing trend is to supply photocopies of articles, rather than send the actual bound volumes of journals on loan. This is often cheaper than postage on a heavy volume; it also eliminates risk of loss or damage to valuable material.

In the case of material from other libraries, a copy is taken which is retained in our library stock and further increases its usefulness.

The library photocopy machine has been consistently used through the year and is giving good service.

Towards the end of the year the Engineering Library stock was moved into temporary accommodation in the Reading Room and in the Geology Department, while new buildings for the Engineering Department are being constructed. This has meant quite a lot of extra work for the library staff and has given an opportunity to sort and weed out old material.

There is still an amount of old material which needs sorting and recording—departmental libraries also need more attention; this work has been hampered this year by inadequate staff and frequent changes.

At December 31, the total book stock was 9,648.

Services to the Public.

The School continued to provide the usual services to industry in addition to its teaching activities. The number of samples submitted for assay and/or mineral determination increased by 23. Four hundred and forty two samples were received and the work done on these samples is shown in Table IX. These samples were received from prospectors and do not include those samples submitted to the Metallurgical Laboratory for pay assay.

Commonwealth Advisory Committee on Advanced Education.

In March the report of the Committee on the Future of Tertiary Education in Australia (Chairman: Sir Leslie Martin) was released and a statement was made in House by the then Prime Minister, The Right Honorable Sir Robert Menzies. The Statement indicated that strong financial assistance would be made available to Colleges providing sound and acceptable tertiary level courses. The School of Mines should qualify for such assistance. Already a grant of £61,500 has been made towards the cost of Stage 1A of the buildings for mining and for engineering.

Over the long vacation a Submission was prepared setting out the requirements of the School for the Triennium 1967/69 and this will go forward to the Committee early in 1966, together with the requirements of other institutions in Western Australia.

Buildings.

During the year a contract was signed for Stage 1A of the new buildings for engineering and for mining. Work will commence early in 1966 and the buildings will be completed late in 1966 or early in 1967. It is hoped that Stage 1B will follow on immediately after the completion of Stage 1A and that the whole building will be completed by the end of 1967. A grant of £61,500 was received through the Commonwealth Committee on Advanced Education towards the cost of Stage 1A.

An overall plan for additional buildings has been prepared. Stage II provides for alterations to the original building—mainly to the chemical laboratories and assaying sections. Stage III provides new buildings for metallurgy and these have been so designed that they will join to Stage 1B buildings. Stake IV provides for new geology and library buildings. Many of the existing buildings will be pulled down.

Requirements of the School

Reference was made in the 1961 Annual Report and in subsequent Reports to the need for additional buildings and to the need for an overall building plan. This has now been prepared and, if followed, will satisfy the building needs of the School so far as these can now be seen. The requirements of the School for staff, buildings, and equipment were set out in the Submission to the Commonwealth Committee on Advanced Education. This provides for additional teaching staff, for additional staff at Technician level, for additional buildings, and for the purchase of major items of equipment which it might be difficult to obtain from State funds alone.

Advisory Committee

The Advisory Committee met seven times during the year. Equipment to the value of £4,367 was approved for purchase from the Apparatus and Equipment Trust Fund. Since this Fund was started in 1948, equipment to value of £31,000 has been purchased from it. This has made available to the School equipment which it might have been difficult through normal channels and has been of great value to students and staff.

Kalgoorlie Metallurgical Laboratory

Two investigations were completed during the year and 275 Certificates were issued. Of the two reports one had reference to gold and one to iron. The Senior Research Metallurgist continued as a member of the Chamber of Mines Metallurgical Committee and also continued to give information to the Public when this was required. The year's work is summarized in Table X and more detailed information is given by the Senior Research Metallurgist in Appendix 3.

Students' Association

The President of the Students' Association was Mr. R. M. King and the usual functions were held during the year. The Ball was less well attended and although socially quite successful was less successsful financially than previous Balls. Interest tended to lag during the year and the work of the Association was done by a small number of students. The hockey team was again successful and won the "A" Grade competition.

NORSEMAN

Enrolments

The number of students enrolled was 50—a decrease of 9 by comparison with the previous year. Table I sets out the individual and class enrolments during the year and for the four previous years; Table II, the enrolments in the various classes; and Table III, the enrolments in the various Courses.

Revenue

The revenue was £193 12s. almost entirely from Class Fees.

Staff

The full-time Staff at Norseman consisted of Mr. Field as Officer in Charge and a cadet, R. E. Perkin was appointed as a cadet in February and has worked well during the year. Seven part-time instructors were employed with Mr. Field to teach 17 subjects.

Examinations

The results of the Annual Examinations are summarized in Tables VI and VII—Table VI is based on class enrolments and Table VII on individual enrolments. The results generally are satisfactory and similar to those for previous years.

The results for individual subjects are given in Appendix I.

Scholarships and Prizes

The Reg Dowson Scholarships for 1965 were awarded to R. E. Perkin and to T. A. Morgan. The two students to whom Reg Dowson Scholarships were awarded in 1964 both completed a satisfactory year's work in 1965. No other awards were made to Norseman students.

Buildings

Generally the buildings are in satisfactory condition, but some internal painting is necessary. Towards the end of the year provision was made for this and it is expected that this work will be done early in 1966.

Advisory Committee

Mr. Dutton, who had been a member of the Advisory Committee since 1942, and Chairman since 1944, resigned from the position of General Superintendent, C.N.G.C. and from the Advisory Committee in March. Mr. Dutton had taken a keen interest in the affairs of the School and was always available for discussions. Members of the Committee wished Mr. Dutton well at an informal meeting held on March 11. Mr. R. Sainsbury was appointed to the Committee in place of Mr. Dutton and was later elected as Chairman.

The Committee met twice during the year.

ACKNOWLEDGMENTS

All members of the Staff have worked well during the year and their co-operation and assistance is gratefully acknowledged. The statistical information for this report has been compiled by the Registrar and office staff in Kalgoorlie and by the Registrar at Norseman. Throughout the year assistance and co-operation has been received from the Advisory Committees, from the Staffs of Mining Companies, from Mines Department Staff and from many others. This assistance is gratefully acknowledged.

R. A. HOBSON,
Director, School of Mines.

March 24, 1966.

TABLE I
ENROLMENTS
1961-1965

Year	Kalgoorlie Individual	Kalgoorlie Class	Norseman Individual	Norseman Class
1961	310	804	65	139
1962	352	945	69	160
1963	365	926	68	140
1964	329	830	59	128
1965	275	858	50	122

TABLE II
CLASS ENROLMENTS
1965

Subject	Kalgoorlie First Term	Kalgoorlie Second Term	Norseman First Term	Norseman Second Term
Chemistry P	19	11	....	....
Chemistry Q	11	9	....	....
Chemistry 1	15	11	....	....
Chemistry 2	5	5	....	....
Analytical Chemistry 1	5	5	....	....
Analytical Chemistry 2	3	3	....	....
Chemical Metallurgy 1	8	8	....	....
Chemical Metallurgy 2	2	2	....	....
Mineral Dressing 1	11	11	....	....
Mineral Dressing 2	4	4	....	....
Mineral Dressing 3	4	4	....	....
Physical Metallurgy	....	....	....	....
Assaying	10	9	....	....
Metallurgy A	....	....	....	....
Mathematics PA	46	32	11	12
Mathematics PB	43	34	10	9
Mathematics QA	43	30	6	6
Mathematics QB	28	18	....	....
Mathematics 1.1	41	28	5	5
Mathematics 1.2	17	17	....	....
Mathematics 1.2 (Stat)	7	....	1	1
Mathematics 2	8	7	....	....
Physics Q	28	19	....	....
Physics 1.1	24	21	....	....
Physics 1.2	17	14	....	....
Physics 2	6	6	....	....
Electronics	8	7	....	....
Engineering Drawing P	30	14	2	2
Engineering Drawing Q	37	30	11	11
Engineering Drawing 1	16	15	3	3
Engineering Drawing W	2	1	7	7
Engineering Design	2	2	....	....
Mechanical Engineering 1	11	10	....	....
Mechanical Engineering 2	2	2	....	....
Electrical Engineering 1	19	17	....	....
Electrical Engineering 2.1	8	8	....	....
Electrical Engineering 2.2	9	9	....	....
Structural Engineering 1	22	22	3	3
Structural Engineering 2.1	8	7	....	....
Structural Engineering 2.2	10	10	....	....
Machine Design 1.1	8	8	....	....
Machine Design 1.2	11	11	....	....
Hydraulics	....	....	....	....
Materials of Construction	....	....	....	....
Workshop Practice 1	12	12	....	....
Workshop Practice A	....	....	9	10
Workshop Practice B	....	....	8	8
Workshop Practice C	....	....	....	....
Workshop Practice D	1	1	....	....
Steam Engine Driving	....	....	....	....
Welding A	14	11	....	....
Welding B	5	4	....	....
Internal Combustion Engine	12	7	17	17
Geology Q	31	22	....	....
Geology 1.1	14	13	6	6
Geology 1.2	5	5	7	7
Geology 2.1	....	....	....	....
Geology 2.2	4	4	....	....
Geology 2.3	4	4	....	....
Geology 3.2	3	3	....	....
Geology 3.3	....	....	....	....
Mining 1	15	11	....	....
Mining 2.1	8	6	....	....
Mining 2.2	3	3	....	....
Mining 3	4	3	....	....
Mining 3 (Sect. B)	2	2	....	....
Mine Ventilation	4	4	....	....
Surveying 1	30	24	6	6
Surveying 2.1	5	5	....	....
Surveying 2.2	4	4	....	....
Mining A	12	8	....	....
Mining B	4	3	....	....
English P	16	9	....	....
English Q	19	11	....	....
English 1	19	17	....	....
Leaving English	....	....	....	....
Mathematics A	....	....	....	....
Mathematics B	....	....	....	....
Physics P	....	....	....	....
Electrical Theory A	....	....	5	5
Electrical Theory B	....	....	....	....
Electrical Theory C	....	....	....	....
Electrical Drawing A	....	....	3	3
Totals	858	677	120	121
Totals, 1964 :	829	651	123	119

TABLE III.

NUMBER OF STUDENTS ENROLLED FOR VARIOUS COURSES.

Course	Kalgoorlie					Norseman				
	1961	1962	1963	1964	1965	1961	1962	1963	1964	1965
ASSOCIATESHIP COURSES										
Mining	24	27	34	31	19	3	6	4	3	1
Metallurgy	17	15	18	20	19	....	....	....	....	....
Engineering	49	44	37	43	31	2	3	....	....	....
Mining Geology	19	11	9	7	7	....	....	....	....	....
Total	109	97	98	101	76	5	9	4	3	1
CERTIFICATE COURSES										
Assayer's	3	6	10	8	4	....	....	....	....	....
Mine Surveyor's	30	27	37	27	30	13	11	9	9	10
Mine Manager's	4	3	....	....	....	....	....	....	....	....
Engineering Draughtsman's	6	8	33	29	24	2	....	8	....	3
Electrical Engineering	2	....	....	....	....	1	1	....	....	....
Mechanical Engineering	1	1	....	....	....	1	....	....	....	....
Total	46	45	80	64	58	17	12	17	9	13
TECHNICIAN COURSES										
Engine Operation and Maintenance	1	1	....	....	....	17	12	2	....	....
Workshop Foreman's	6	2	....	....	....	3	6	....	....	....
Welding	16	24	17	19	11	4	6	7	6	4
Workshop (Mechanical)	....	....	....	1	....	....	....	12	1	20
Workshop (Electrical)	....	....	2	....	....	....	....	5	....	5
Mine Manager's (2nd class)	....	....	5	8	7	....	....	....	1	2
Total	23	27	24	28	18	24	24	26	8	31
NO SET COURSE										
Preparatory subjects	44	38	27	17	26	3	11	11	....	3
Qualifying subjects	....	22	17	17	16	....	....	....	....	....
External students	3	....	....	2	....	....	....	....	....	....
Junior and Leaving	9	28	32	18	7	....	....	....	....	....
University	4	3	1	1	2	....	....	....	....	....
Others	72	92	86	81	72	16	12	10	39	2
Total	132	183	163	136	123	19	23	21	39	5
TOTAL FOR YEAR	310	352	365	329	275	65	68	68	59	50

TABLE IV

REVENUE 1963-1965

	Kalgoorlie			Norseman		
	1963	1964	1965	1963	1964	1965
Class Fees	1,514 4 0	1,730 5 6	1,501 12 6	139 4 6	207 0 6	185 12 0
Registration Fees	82 0 0	....*	....*	20 0 0	....*	....*
Lecture Note Fees	64 17 6	60 7 6	51 10 0	10 15 0	9 2 6	8 0 0
Laboratory Deposits	150 0 0	110 0 0	94 0 0	....	8 0 0	....
Supplementary Examinations	42 0 0	50 0 0	36 0 0	6 0 0	4 0 0	....
Students' Association	219 10 0	218 15 0	186 15 0	....	....	....
Apparatus and Equipment Trust Fund	1,000 0 0	....	2,000 0 0	....	....	....
Metallurgical Laboratory Trust Fund	1,050 18 0	940 17 0	502 15 6	....	....	....
Commonwealth Grants—Research Laboratory—Trust Fund	2,700 0 0	2,851 10 0	3,030 0 0	....	....	....
Mine Managers and Underground Supervisors	50 16 6	53 11 0	52 10 6	....	....	....
Sundries	66 9 0	181 19 3	92 14 10	....	....	....
Total	£6,940 15 0	£6,197 5 3	£7,547 18 4	£175 19 6	£228 3 0	£193 12 0

* Registration fees discontinued

TABLE V

NUMBER OF STUDENTS PAYING FEES 1963-1965

Group No.	Description	Kalgoorlie						Norseman					
		1963	1964	1965				1963	1964	1965			
		Total	Total	Full Time	Part Time	External	Total	Total	Total	Full Time	Part Time	External	Total
1	Students under 18. Class fees, deposits, lecture notes fee, Students' Association	104	86	8	69	....	77	28	24	....	16	....	16
2	Students 18-20. Class fees and other fees as for Group 1	100	76	8	50	....	58	20	19	....	18	....	18
3	Students 21 and over. Class fees and other fees as for Group 1	129	147	11	96	....	107	20	14	....	15	....	15
4	Returned Servicemen. Exempt Class fees	22	9	....	9	....	9	....	1	....	....	....	....
5	Staff. Exempt class fees	9	9	....	22	....	22	....	1	....	1	....	1
6	Scholarship Holders. Exempt class fees	1	2	2	....	....	2	....	....	....	....	....	....
		365	329	....	....	....	275	68	59	....	....	....	50

TABLE VI

RESULTS OF ANNUAL AND OF SUPPLEMENTARY EXAMINATIONS BASED ON CLASS ENROLMENTS, 1961-1965

	Kalgoorlie					Norseman				
	1961	1962	1963	1964	1965	1961	1962	1963	1964	1965
Class Enrolments = A	804	945	931	827	858	139	160	140	115	122
Number of entries for Annual Examinations = B	544	609	633	581	558	96	118	96	97	82
B/A per cent.	68	64	68	70	65	70	74	69	84	67
Number of passes at Annual Examinations as a per cent. of A	51	49	49	53	53	48	51	54	75	55
Number of passes at Annual Examinations as a per cent. of B	76	75	71	75	81	70	69	79	89	82
Number of passes at Annual Examinations and Supplementary Examinations as a per cent. of A	53	52	52	57	54	54	53	56	75	56
Number of passes at Annual Examinations and Supplementary Examinations as a per cent. of B	79	81	76	81	82	78	71	81	89	83

TABLE VII

STUDENTS SITTING FOR ANNUAL EXAMINATIONS. 1963-1965

Course	Kalgoorlie						Norseman					
	1963		1964		1965		1963		1964		1965	
	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	98	95	101	88	76	95	4	100	3	67	1	100
Certificate	80	66	65	78	58	66	17	88	9	100	13	85
Technician	24	71	28	61	18	67	26	85	8	87	31	68
No Set Course	163	46	135	50	123	53	21	52	39	89	5	80
	365	66	329	68	275	68	68	76	59	81	50	74

TABLE VIII

COURSES COMPLETED 1961-1965 KALGOORLIE AND NORSEMAN

	1961	1962	1963	1964	1965
Associateship Courses—					
Mining	2	1	3	10	4
Metallurgy	5	2	1	2	2
Engineering	10	3	2	8	6
Mining Geology....	....	4	1	....	3
	17	10	7	20	15
Certificate Courses—					
Assayer's	1	6	1	6	4
Mine Manager's....	1	1	2	4	1
Mine Surveyor's	11	6	5	3	10
Engineering Draughtsman's	2	2	4	8	6
Electrical Engineering	1	1	....	1	....
Mechanical Engineering	....	1	....	1	....
	16	17	12	23	21
Technician Courses—					
Engine Operation and Maintenance	1	1	1	....	....
Workshop Foreman's	1	1	....	1	....
Welding	1	....	1	3	1
Workshop Practice (Mechanical)	....	....	....	....	1
Workshop Practice (Electrical)	....	....	....	....	....
Mine Manager's (2nd Class)	....	....	....	1	2
	3	2	2	5	4

TABLE IX

WORK DONE ON SAMPLES RECEIVED FROM PROSPECTORS AND OTHERS KALGOORLIE

	1961	1962	1963	1964	1965
Assay—gold	177	325	239	261	209
Assay—gold and other constituents	2	11	15	4	9
Assay—metals other than gold....	23	46	57	20	54
Assay plus mineral determination	16	11	....	11	18
Mineral examination	117	138	108	100	136
Rejected or transferred to Metallurgical Laboratory pay	6	30	39	23	16
	341	561	458	419	442

TABLE X

KALGOORLIE METALLURGICAL LABORATORY SUMMARY OF WORK

	1961	1962	1963	1964	1965
Investigations outstanding (January 1)	2	6	5	6	3
Investigations asked for (735-736)	7	5	5	4	2
	9	11	10	10	5
Investigations completed	3	5	3	7	2
Investigations outstanding (December 31)	6	5	6	3	3
Investigations cancelled	....	1	1	....	....
	9	11	10	10	5
Certificates issued (assays, analyses, etc.)	469	391	414	406	275

School of Mines of Western Australia

APPENDIX 1

Annual Examinations 1965

Pass List

Kalgoorlie

Passes are in order of merit.

(E) denotes equal.

(*) denotes year fee scholarship.

Chemistry P

Credit:

*Thompson, R. V.

Pass:

Macdonald, A.
Healy, R. W.
E {Jasson, T. J.
  {Simmons, T. H.
Edwards, R. J.

Supp. Exam Granted

Finnegan, T. J.
Vagg, P.

Chemistry Q

Credit:

*Brooks, T. E.

Pass:

Egan, H. P.
E {King, J. C.
  {Griffin, W. C.
Molloy, L. J.
Stevens, R. G.
Mason, R. E.

Supp. Exam. Granted

Loxton, I. W.

Chemistry 1

Pass:

Dunstan, P. L.
Mykytiuk, A.
Rear, B. J.
Symons, J. W.
Stodart, I. S.
Speering, P. J.
Fiegert, J.

Chemistry 2

Credit:

*Tillotson, D. L.

Pass:

Brinsden, W. K.
Lethlean, W. R.
Dombrose, E. J.
Wills, M. F.

Analytical chemistry 1

Credit:

*Ridley, R. H.
Lethlean, W. R.

Pass:

Tillotson, D. L.
Dombrose, E. J.
Renton, K. J.

Analytical Chemistry 2

Credit:

*Botica, G. G.

Pass:

Tichelaar, P. D.

Mineral Dressing 1

Credit:

*Rear, B. J.
Lethlean, W. R.
Dunstan, P. L.

Pass:

Ridley, R. H.
Haule, E. F.
Phillips, B. M.
Symons, J. W.
Sands, D. J.
Molloy, L. J.

Mineral Dressing 2

Credit:

*Tillotson, D. L.
Tichelaar, P. D.

Pass:

E {Brinsden, W. K.
Dombrose, E. J.}

Mineral Dressing 3

Pass:

Absolon, V. J.
Botica, G. G.
Head, D. J.
Faulkner, D. A.

Chemical Metallurgy 1

Credit:

*Tichelaar, P. D.
Brinsden, W. K.
Tillotson, D. L.

Pass:

E {Faulkner, D. A.
Botica, G. G.}
Dombrose, E. J.
Head, D. J.
Wills, M. F.

Chemical Metallurgy 2

Pass:

Black, N. C.
Absolon, V. J.

Assaying

Pass:

Dunstan, P. L.
Rear, B. J.
Livingstone, G.
Phillips, B. M.
Symons, J. W.
E {Loxton, I. W.
Molloy, L. J.
Muze, K. A.}

Mathematics, PA

Credit:

*Rendell, T. S.
Riebe, L. M.
Goode, M. J.

Pass:

Radosevich, J. R.
Chegwidden, P. J.
Fitzgerald, K. J.
Kelsall, D.
Finnegan, T. J.
Brierley, G. B.
Tyler, P. J.
Vagg, P.

Mathematics PB

Credit:

*Rendell, T. S.

Pass:

Goode, M. J.
Chegwidden, P. J.
Riebe, L. M.
E {Finnegan, T. J.
MacDonald, R.}
Tyler, P. J.
Rowe, B. E.
Radosevich, J. R.
Fitzgerald, K. J.
Vagg, P.
Selsmark, P. B.

Mathematics QA

Credit:

*Brooks, T. E.
Bowman, G. J.

Pass:

Cook, L. A.
Stevens, R. G.
Willis, L. G.
Waldron, E. H. J.
Griffin, W. C.
Nicholson, R. E.
Ralph, F. K.
Doig, N. E.
Hewitt, G. P.

Mathematics QB

Credit:

*Brooks, T. E.
Willis, L. G.
Zamorski, G.

Pass:

King, J. C.
Nicholson, R. E.
Waldron, E. H. J.
Stevens, R. G.
Griffin, W. C.
Cook, L. A.

Mathematics 1.1

Credit:

*Mandara, E. D.
Phillips, B. M.
McKay, A. A.
E {Brioschi, D. G.
Symons, J. W.}

Pass:

E {Dunstan, P. L.
Speering, P. J.
Stodart, I. S.}
E {Dobson, W. H.
Rear, B. J.}
Haule, E. F.
Phillips, K. J.
Mainwaring, D. D.
Brown, R. J. McK.
Livingstone, G.
Foxton, A. J.

Supp. Exam. Granted:

Renton, K. J.

Mathematics 1:2

Pass:

May, A. J.
Dombrose, E. J.
Muze, K. A.
Phillips, B. M.
Speering, P. J.
Miller, T. D.
E {Brioschi, D. G.
Kew, L. J.}
Golding, P. D.

Supp. Exam. Granted:

Forrest, A.
Tastula, R. A.
Ward, W. S.
Tillotson, D. L.

Mathematics 1.2 (Stats).

Pass:

Mahalingham, S. S.

Mathematics 2.

Credit:

*Carroll, G. R.

Pass:

Woolhouse, M. L.
Procter, J. D.
Ralph, G. M.
Magnus, E. R.

Supp. Exam. Granted:

Cluss, W. W.

Physics Q.

Credit:

*Brooks, T. E.
Willis, L. G.

Pass:

E {Nicholson, R. E.
Rear, B. J.}
Cook, L. A.
E {King, J. C.
Renton, K. J.}
Stevens, R. G.
Griffin, W. C.
Van Raven, T. W.
Winner, P. D.

Physics 1.1.

Pass:

Stodart, I. S.
Mandara, E. D.
Haule, E. F.
Dunstan, P. L.
Speering, P. J.
Symons, J. W.
E {Brioschi, D. G.
Wills, M. F.}
Banks, F. R.
Erbe, J. D.
Brown, R. J. McK.

Supp. Exam. Granted:

Kew, L. J.

Physics 1.2.

Credit:

E {*Mandara, E. D.
*McKay, A. A.}

Pass:

E {Dunstan, P. L.
George-Kennedy, R. J.}
Speering, P. J.
Nowland, P. J.
Brioschi, D. G.
E {Forrest, A.
Golding, P. D.}
Phillips, B. M.
Haule, E. F.

Physics 2.

Credit:

*Carroll, G. R.

Pass:

Marshall, D. A.
Magnus, E. R.
Cluss, W. W.

Electronics.

Credit:

*Woolhouse, M. L.
Pearson, C. A. L.
Carroll, G. R.

Pass:

May, A. J.
McRostie, B. L.
Rice, M. J.
Dombrose, J. S.

Engineering Drawing P.

Credit:

*Rendell, T. S.
Mandara, E. D.
Cruickshank, M. R.
Chegwidden, P. J.

Pass:

Selsmark, P. B.
Riebe, L. M.
Rowe, B. E.
Radosevich, J. R.
Vagg, P.
Callaghan, K. P.

Engineering Drawing Q.

Credit:

*Stevens, R. G.
Willis, L. G.
Wearne, J.
Haule, E. F.
Mainwaring, D. D.

Pass:

Visser, F. A.
Erbe, J. D.
Brooks, T. E.
Brierley, G. B.
Griffin, W. C.
Taaffe, L. D.
Kelsall, D.
Symons, J. W.
Zamorski, G.
Fitzgerald, K. J.
Mykytiuk, A.
Smales, R. T.

Engineering Drawing 1.

Credit:

*Cluss, W. W.
George-Kennedy, R. J.
Stevens, R. J.
Schultz, K.
King, J. C.

Pass:

Willis, L. G.
Miller, T. D.
Brioschi, D. G.
Nowland, P. J.
Kew, L. J.
Tastula, R. A.
Healy, R. W.

Engineering Design.

Credit:

*Ward, W. S.

Pass:

Gilbert, N. B.

Machine Design 1.1.

Credit:

*Carroll, G. R.
May, A. J.

Pass:

Wallis, H. W.
Gilbert, N. B.
Forrest, A.
Golding, P. D.

Machine Design 1.2.

Credit:

*Kelly, J. P.

Pass:

King, R. M.
E {Griffin, R. J. / Karczub, L. M. / Maley, W. S.}
E {Leslie, W. E. / Woolhouse, M. L.}
Fong, K. H.
E {Cumming, G. M. / Hobson, J. C.}
Procter, J. D.

Mechanical Engineering 1.

Credit:

*Carroll, G. R.
Kelly, J. P.

Pass:

Gilbert, N. B.
Forrest, A.
May, A. J.
Mahalingham, S. S.
Golding, P. D.
Ward, W. S.
Bussell, L. M.

Mechanical Engineering 2

Pass:

Procter, J. D.
Fong, K. H.

Electrical Engineering 1

Credit:

*Carroll, G. R.
George-Kennedy, R. J.

Pass:

Tillotson, D. L.
Mahalingham, S. S.
Forrest, A.
Griffin, R. J.
Dombrose, J. S.
May, A. J.
Dombrose, E. J.
Bussell, L. M.
Foxton, A. J.
Golding, P. D.
Nowland, P. J.
Walker, M. C.
Leslie, W. E.
Bayly, J. G.

Electrical Engineering 2.1

Pass:

Marshall, D. A.
Cumming, G. M.
Pearson, C. A. L.
Kelly, J. P.
King, R. M.
Procter, J. D.
Fong, K. H.

Supp. Exam. Granted:

McRostie, B. L.

Electrical Engineering 2.2

Credit:

*Ralph, G. M.
Pearson C. A. L.
King, R. M.
McRostie, B. L.
Karczub, L. M.

Pass:

Fong, K. H.
Procter, J. D.
Maley, W. S.

Structural Engineering 1

Credit:

*May, A. J.

Pass:

Carroll, G. R.
E {Griffin, R. J. / Bayly, J. G.}
Forrest, A.
Tennant, T.
Wallis, H. W.
E {Dombrose, J. S. / Leslie, W. E.}
Golding, P. D.
Loxton, I. W.
Ward, W. S.

Structural Engineering 2.1

Credit:

*Woolhouse, M. L.
Maley, W. S.
Procter, J. D.

Pass:

King, R. M.
Karczub, L. M.
Fong, K. H.

Structural Engineering 2.2

Credit:

*Ralph, G. M.
E {Kelly, J. P. / Marshall, D. A.}
Pearson, C. A. L.
E {Maley, W. S. / Karczub, L. M.}

Pass:

McRostie, B. L.
Fong, K. H.
Procter, J. D.

Workshop Practice 1

Credit:

*Stevens, R. G.
Brioschi, D. G.

Pass:

Hobson, J. C.
Thompson, R. V.
Willis, L. G.
King, J. C.
Zamorski, G.
Foxton, J. A.
Mason, R. E.
Bayly, J. G.
Magnus, E. R.
Miller, T. D.

Workshop Practice D

Pass:

Fry, B.

Internal Combustion Engines

Credit:

*Doyle, D. McD.

Pass:

Jordan, G. H.
Godfrey, G. R.
Cotterell, R. G.
Alexander, W. J.

Welding A

Credit:

*Crocos, A. J.

Pass:

Cotterell, R. G.
Morris, D. G.
Edmonds, G. S.
Davis, K. J.
Pearce, W. R.
Hardy, E. J.
Marmion, E.
Vitucci, V.

Exemption Granted from Attending at Lectures in 1966:

Paull, C. R.

Welding B

Pass:

Condren, B. D.
Alexander, W. J.
Teede, J. P.
Bailey, J. F.

Geology Q

Credit:

*Mandara, E. D.
Griffin, R. J.

Pass:

Griffin, W. C.
Maley, D. K.
Brooks, T. E.
Cruickshanks, M. R.
Speering, P. J.
Ball, G. R.
Biltoft, C. J.
Wearne, J.
E {Abatematteo, G. / Barron, T. D. / Hodge, F.}

Geology 1.1

Credit:

*Stodart, I. S.

Pass:

Dunstan, P. L.
Mandara, E. D.
Phillips, B. M.
E {Haule, E. F. / Symons, J. W.}

Geology 1.2

Pass:

Stodart, I. S.
Phillips, B. M.
Lewis, R. P. J.

Geology 2.2

Pass:

Smurthwaite, A. J. N.
George-Kennedy, R.J.

Geology 2.3

Credit:

*Tichelaar, P. D.

Pass:

E {Absolon, V. J. / Faulkner, D. A.}
Renton, K. J.

Geology 3.2

Pass:

Sands, D. J.

Mining 1

Pass:

Phillips, K. J.
Mandara, E. D.
Chamberlain, E. H. N.
Tastula, R. A.
Smurthwaite, A. J. N.
Griffin, R. J.
Molloy, L. J.
Lewis, R. P. J.
Haule, E. F.

Deferred Final:

Stodart, I. S.

Mining 2.1

Credit:

*Crew, R. J.
Gould, R. J.

Pass:

Sands, D. J.
Lindfield, N. W.

Sup. Exam. Granted:

Muze, K. A.

Mining 2.2

Pass:

Tennant, T.
Phillips, B. M.
Muze, K. A.

Mining 3

Credit:

*Schultz, K.

Pass:

Cruickshank, A. C.
Loxton, I. W.
Powell, P.

Mining A

Credit:

*Leggerini, R. J.
Kitenbergs, J. A.

Pass:

Brooks, B. E.
Burton, E. A.
Unkovitch, A.
Higgins, K. A.

Mining B

Credit:

*Byrnes, F. E.
Abatematteo, G.

Pass:

Hodge, F.

Mine Ventilation

Pass:

Mahalingham, S. S.
Loxton, I. W.

Surveying 1

Credit:

*Chamberlain, E. H. N.

Pass:

Carroll, G. R.
Phillips, K. J.
Marshall, D. A.
Mandara, E. D.
Willis, L. G.
Forrest, A.
Abatematteo, G.
Tastula, R. A.
May, A. J.
Woolhouse, M. L.
Mainwaring, D. D.
Molloy, L. J.
Haule, E. F.
Brioschi, D. G.
Hodge, F.

Exemption granted Practical Work in 1966.

Cumming, G. M.
Zamonski, G.

Exemptions Granted from attending at Lectures in 1966:

Hobson, J. C.

Surveying 2.1

Pass:

Tennant, T.
Curran, B. G.
Pivac, A. M.
Crew, R. J.
McGee, A. R.

Surveying 2.2

Credit:

*Crew, R. J.

Pass:

Curran, B. G.
McGee, A. R.
Banks, F. R.

English P

Credit:

*Rendell, T. S.

Pass:

E {Brierley, G. B. / Chegwidden, P. J. / Cowin, A. B.}
E {Finnegan, T. J. / Hopkins, J. M.}

Supp. Exam. Granted:

Vagg, P.

English Q

Credit:

*Stevens, R. G.

Pass:

Rear, B. J.
Griffin, W. C.
Willis, L. G.
Brooks, T. E.
E {Livingstone, G.
Zamorski, G.
Ridley, R. H.}

Supp. Exam. Granted:

Symons, J. W.
Van Raven, T. W.

English 1

Pass:

Tichelaar, P. D.
E {Dombrose, E. J.
Sands, D. J.
Tillotson, D. L.}
Cumming, G. M.
May, A. J.
Fong, K. H.
Ward, W. S.
Bussell, L. M.
Procter, J. D.
Gilbert, N. B.
King, R. M.
Griffin, R. J.

Supp. Exam. Granted:

Leslie, W. E.

SCHOOL OF MINES OF WESTERN AUSTRALIA.

ANNUAL EXAMINATIONS—1965.

PASS LIST.

NORSEMAN.

Mathematics PA.

Credit:

*James, M.

Pass:

Morton, P. W.
Van Gelderen, F. P. M. A.
Steel, D. K.
Pickering, W. F.
Jenkins, R. L.

Mathematics PB.

Credit:

*James, M.

Pass:

Van Gelderen, F. P. M. A.
Darch, R. J.
Morton, P. W.

Mathematics QA.

Pass:

Perkin, R .E.
Stewart, D. A.
E {Van Gelderen, I. M.
Beattie, R. J. S.}

Mathematics 1.1.

Pass:

Sweet, K. A.
Cook, G. J. S.

Mathematics 1.2 (Stats).

Pass:

Cook, G. J. S.

Engineering Drawing P

Credit:

*James, M.

Pass:

Perkin, R. E.
Beattie, R.

Engineering Drawing Q.

Pass:

Darch, R. J.
Morgan, T. A.

Engineering Drawing 1.

Pass:

Lea, R. J.

Structural Engineering 1.

Pass:

Kerr, P. H.
Lea, R. J.

Internal Combustion Engines.

Credit:

*Green, T. D.
Stewart, D. A.

Pass:

Philippe, G. R.
Morgan, T. A.
Jones, H. B.
Giles, T. E.
Ismail, K. G.
Jenkins, R. L.
E {Fleay, J. R.
Foote, S. P.}
Giles, W. K.

Engineering Drawing W.

Pass:

Fleay, J. R.
Perkin, D. A.
Green, T. D.
Giles, T. E.
Jones, H. B.

Geology 1.1.

Pass:

Sweet, K. A.
Beattie, R. J. S.
Swain, G. B.

Geology 1.2.

Pass:

Cook, G. J. S.

Surveying 1.

Pass:

Beattie, R. J. S.
Sweet, K. A.

Supp. Exam. Granted in Paper B:

Churchill, W. G.

Electrical Theory A.

Pass:

James, E. P.
Darch, R. J.
Perkin, R. E.
Horan, R. J.

Electrical Drawing A.

Pass:

Horan, R. J.
James, E. P.
Perkin, R. E.

Workshop Practice A.

Pass:

Fleay, J. R.
Van Gelderen, I. M.
Temple, E. D.
Morgan, T. A.
Ismail, K. G.
Pickering, W. F.

Workshop Practice B.

Pass:

Perkin, D. A.
Foote, S. P.
Philippe, G. R.
Green, T. D.
Jones, H. B.
Freeman, P. G.
Murphy, R. J.

SUPPLEMENTARY EXAMINATIONS FEBRUARY, 1965

The following students passed in the subjects listed below:

* denotes deferred final taken in February, 1965.

KALGOORLIE

Chemistry Q

Fiegert, J.

Chemistry 1

Dombrose, E. J.
Lethlean, W. R.

Mathematics Q

Foxton, J. A.

Mathematics 1.1

Golding, P. D.
Kew, L. J.
Tastula, R. A.
Walker, M. C.
Wills, M. F.

Mathematics 1.2

Bussell, L. M.
Nowland, P. J.
Stokes, M. C.

Mathematics 1.2 (Stats)

McGee, A. R.
McKay, I. D.
Satapuntu, S.

Physics Q

Cowin, A. B.
Kew, L. J.
Rojo, K. H.

Physics 2

Dombrose, J. S.

Electronics

Griffin, R. J.
Leslie, W. E.

Geology Q

Livingstone, G.
Mainwaring, D. D.

Geology 1.2

Georgenyi, G. J.
Satapuntu, S.

Mining 1

*Georgenyi, G. J.

Surveying 1

Fisher, J. A. S.
Griffin, R. J.

Surveying 2.1

Satapuntu, S.
Taaffe, L. D.

English P

Devine, W. S.

SCHOOL OF MINES OF WESTERN AUSTRALIA

APPENDIX 2

SCHOLARSHIPS AND PRIZES 1965

MINES DEPARTMENT

Senior Scholarship: Brooks, T. E.

CHAMBER OF MINES PRIZES

Metallurgy: Lethlean, W. R.
Mining: Mandara, E. D.
Engineering: Kelly, J. P.
Geology: No award.

SCHOOL OF MINES STUDENTS' ASSOCIATION SCHOLARSHIPS

Mining: George-Kennedy, R. J.
Metallurgy: Tichelaar, P. D.
Engineering: Woolhouse, M. L.
Geology: No award.

INSTITUTE OF MINES SURVEYOR'S PRIZE

£10 Prize: Chamberlain, E. H. N.
£5 Prize: Tennant, T.

SOCIETY OF THE W.A. SCHOOL OF MINES ASSOCIATES' PRIZE

Cook, L. A.

REG DOWSON SCHOLARSHIPS

Group "A": Perkin, R. E.
Group "B": Morgan, T. A.

ROBERT FALCONER PRIZES

First Prize (£5): No student eligible.
Second Prize: No student eligible.

C. A. HENDRY PRIZE

McKay, A. A.

WESLEY LADIES GUILD

Stevens, R. G.

APPENDIX 3

KALGOORLIE METALLURGICAL LABORATORY

by

E. Tasker, A.W.A.S.M. (Met.), A.M.Aus.I.M.M.
Senior Research Metallurgist.

INTRODUCTION

Two reports of investigations and two hundred and seventy four certificates of testing and analysis 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 Organisation,

314 Albert Street,
East Melbourne, C.2.,
Victoria.

from whom copies of the report can be obtained, usually six months after date of issue.

In addition to the reports issued, one other investigation was 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 a project for the Metallurgical Committee of the Chamber of Mines of Western Australia.

COMPLETED INVESTIGATIONS

Report No. 734.

Cyanidation tests were carried out on pyritic concentrates from the Enterprise Mine, Pine Creek, Northern Territory. The auriferous arsenopyrite was refractory to cyanidation and gold extraction was poor. Fine grinding of the concentrates before cyanidation did improve the gold recovery, but residues were still relatively high in gold values.

Report No. 735.

A low-grade vanadiferous iron ore from Coates, near Wundowie, Western Australia was the subject of this report.

The object of the investigation was to produce a high-grade iron oxide concentrate containing the vanadium by some flotation technique.

A considerable number of flotation tests were carried out using a variety of reagents and techniques but a concentrate of the required grade (60 per cent. iron) was not produced.

INCOMPLETE INVESTIGATIONS

Report No 728.

Further test-work on up-grading a cement lime rock from Fremantle, Western Australia is still pending following the issue of an interim report.

Report No. 729.

Test-work was carried out on an auriferous chalcopyrite concentrate from the Paris Gold Mine, Widgiemooltha, Western Australia. The test-work is now completed and a report will be issued.

Report No. 736.

Test-work was in progress on a lead ore from the Mary Springs Lead Mine, near Geraldton, Western Australia.

E. TASKER,
Senior Research Metallurgist.

KALGOORLIE METALLURGICAL LABORATORY
Summary of Year's Work, 1965

Report No.	Owner	State	Locality	Ore Type	Type of Investigation	Confidential Until	Number of Metallurgical Tests	Number of Assays: Gold	Number of Assays: Other
734	Director of Mines, Darwin	N.T.	Pine Creek	Auriferous concentrates	Cyanidation tests	26/8/65	14	21	52
735	Director, Government Chemical Laboratories	W.A.	Coates, near Wundowie	Vanadiferous Iron Ore	Flotation tests	5/5/66	30	....	121
....	Certificate Nos. 2921–3021, 3023–3105, 3107–3170, 3177–3203	....	....	....	....	....	....	715	693
....	Free Assays	....	....	....	....	....	....	235	86
....	School of Mines	....	....	....	....	....	....	1	5
						Totals	44	972	957

THE FOLLOWING INVESTIGATIONS WERE INCOMPLETE OR PENDING AT 31st DECEMBER, 1965 :—

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
736	T. A. Bridson, Geraldton	W.A.	Mary Springs Lead Mine	Lead	Concentration tests	....	4	....	20
						Totals	90	1,072	1,068

(10)—25843

DIVISION VI

Annual Report of the Inspection of Machinery Branch of the Mines Department for the Year 1965

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 ended 1965.

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 disinfaction 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 277 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 2,483 were not in service.

Return No. 3.

This contains a summary of operations for the year.

Manufacture of boilers in this State for export to other Australian States shows an increase of 10 per cent. compared with 1964. One hundred and fifteen boilers were sent to the Eastern States, and, additionally ten went to countries outside Australia.

Imports into Western Australia from other States showed a slight drop while from other countries there has been an increase of approximately 26 per cent.

Exports from this State consist mainly of package boilers manufactured by one firm. Imports differ from this in that they are mainly in the pressure vessel field and are largely air and gas receivers. This follows the pattern of 1964 and has been brought about by the large increase in the use of liquid petroleum gas as a heating and cooking medium, and the use of anhydrous ammonia in agriculture.

Construction of large diesel powerhouses accounts for the introduction of imported starting air receivers which are supplied with the engines.

Expansion of industry continued during the year with the alumina refinery industry doubling capacity which means approximately another thirty vessels. Additionally three iron ore projects are in progress, resulting in many pressure vessels, mainly air receivers, being put into use in that field. In addition a number of smaller enterprises were started, requiring more boilers and pressure vessels for process work.

RETURN No. 1.

Showing the Number of Boilers of Each Type, and Country of Origin of New Registrations, for the Year ended, 31st December, 1965.

	U.S.A.	United Kingdom	Eastern States	Japan	Norway	Germany	Belgium	Western Australia	Unknown Resource	Total
Return Multi. Stat. Intern. Fired	....	....	....	....	....	....	....	140	....	140
Cornish	....	....	....	....	....	....	....	2	....	2
Semi Cornish	....	....	....	....	....	....	....	1	....	1
Digester	....	....	4	....	1	....	....	5	1	11
Vulcaniser	....	....	12	....	....	....	....	7	1	20
Steam Jacketed Vessels	....	1	1	....	....	....	....	21	3	26
Sterilisers	....	....	12	....	....	2	....	114	....	128
Air Receivers	6	47	62	....	....	....	1	119	17	252
Gas Receivers	3	1	20	1	....	....	....	67	....	92
Autoclaves	....	1	3	....	....	1	....	8	....	13
Return Multi. Stat. U/fired	....	....	1	....	....	....	....	....	....	1
Vert. Stationary	....	....	1	....	....	....	....	....	....	1
Water Tube	....	1	2	....	....	....	....	1	....	4
Lorance	....	....	1	....	....	....	....	....	....	1
Cylindrical	....	....	1	....	....	....	....	....	....	1
Total	9	51	120	1	1	3	1	485	22	693

RETURN No. 2.

Showing Classification of Various Types of Useful Boiler in Proclaimed Districts on 31st December, 1965.

Types of Boilers	Districts Worked from Perth	Districts Worked from Kal-goorlie	Total
Lancashire	34	27	61
Cornish	207	66	273
Semi Cornish	14	1	15
Vert. Stationary	395	44	439
Vert. Port.	30	12	42
Vert. Multi Stat.	39	4	43
Vert. Multi Port.	4	1	5
Vert. Pat. Tubular	49	....	49
Loco. Rect. F/Box Stat.	72	20	92
Loco. Rect. F/Box Port.	144	18	162
Loco. Circ. F/Box Port.	84	3	87
Locomotive	76	12	88
Water Tube	550	59	609
Ret. Multi U/Fired Stat.	256	8	264
Ret. Multi S. U/Fired Port.	....	5	5
Ret. Multi Int. Fired Stat.	271	9	280
Sterilisers	806	66	872
Autoclaves	114	2	116
Digesters	315	6	321
Gas Receivers	672	2	674
Air Receivers	2,448	790	3,238
Vulcanisers	448	10	458
Steam Jacketed Vessels	734	15	749
Not Elsewhere Specified	275	5	280
Total Registrations Useful Boilers	8,037	1,185	9,222
Total Boilers out of use, 31/12/65	1,655	828	2,483

RETURN No. 3.

Showing Operations in Proclaimed Districts. During Year ended 31st December, 1965.

Boilers	Districts Worked from Perth	Districts Worked from Kal-goorlie	Totals	
			1964	1963
Total number of useful boilers registered	8,037	1,185	9,222	8,735
New Boilers registered during year	690	3	693	589
Boilers inspected thorough	5,191	349	5,540	5,138
Vessels exempt under Act constructed for export thorough	161	....	161	28
Boilers inspected working	1,191	8	1,199	908
Boilers condemned during year temporarily	1	....	1	5
Boilers condemned during year permanently	72	5	77	42
Boilers sent to other states during year	115	....	115	104
Boilers sent from other states during year	120	3	123	123
Boilers sent from other countries during year	66	....	66	49
Boilers sent to other countries during year	10	....	10	2
Transferred to other Departments	1	....	1	....
Transferred from other Departments	2	....	2	1
Re-instated	....	....	....	2
Converted	....	....	....	1
Number of notices of repairs issued during year	598	26	624	570
Number of certificates issued including those issued under Section 30 during the year	5,206	349	5,555	5,159

MAINTENANCE AND MISCELLANEOUS.

Maintenance and operation during this year have again been of quite a high standard, particularly in large installations. However in small boiler plants there is a lack of mechanical knowledge and appreciation of the requirements in regard to boilers. This applies particularly to routine procedures in operation and use of feed water treatment which is generally most necessary in W.A. Routine procedures in operation applies to automatically controlled and manually operated boilers in that a basic understanding of the elementary principles involved makes the boiler owner or attendant much more efficient on the job. To this end visits by officers of this Branch to boiler installations, when the boilers are under steam, and with sufficient time to be able to check the operation thoroughly, then to instruct and advise on any short comings are most desirable. Unfortunately owing to shortage of staff and increasing volume of work, we have been unable to give anything like sufficient time to this phase.

In the field of water treatment there are a number of reputable proprietary lines available. Like boilers these are satisfactory if used correctly and to the maker's instructions. However some of them require careful attention to chemical testing of the water and variations of treatment to suit. This can be done in large plants where generally there are chemists or skilled men to attend to this. However it is the small operator who requires a simplified treatment with which he can cope. With such small plants the boiler is usually only opened up once a year when it has to be prepared for inspection so that for twelve months the treatment can be bad but is only found after this long period. It is possible that a great deal of damage can be done in this time.

Manufacture of boilers and pressure vessels in W.A. has continued to be generally of a high standard, particularly with the established experienced firms. It is usual that new firms entering the boiler or pressure vessel fabrication field require quite a lot of the Department's time until we are sure they are on the right track.

The number of boilers and pressure vessels registered during the year shows an increase of 487.

Section 2.

EXPLOSIONS AND INTERESTING DEFECTS.

Once again it is with relief, but no sense of complacency that I can report that there was no boiler or pressure vessel explosion during 1965. However there were two fatalities due to gas escape from pressure vessels which are recorded under Case A and Case B in the following detailed reports. In the former two men died and two were severely burnt, and in the latter one man died. In addition there are several other incidents concerning boilers and pressure vessels which are considered worthy of note and are also detailed hereunder.

A.

This instance concerns a large L.P. gas vessel, a propane work drum used in circuit in a de-asphalting process. It was usual to drain this vessel to separate the asphalt from the propane several time a shift. It had been reported however that the drain was blocked. Prior to the mishap fitters were working on this line clearing it with rods. To do this a cock and a valve at the bottom of the drain line approximately 5 ft. above ground level were open but another valve on the line located near to the vessel was closed. The vessel was mounted on concrete blocks approximately 25 ft. above ground level. When the fitters notified the plant operator that the line was clear the operator proceeded to blow through the line. This was usually done by having the valve at the top of the drain pipe full open, the cock in the line near the bottom full open and controlling the flow by partially opening the bottom valve.

While the plant operator was draining the line the fitters proceeded to gather up their tools. Unfortunately the plant operator was one of the badly burnt victims who subsequently died, so that what actually had been done to the valve is not known. It is known that the drainage commenced because the gas was heard escaping. Then it appears the gas drifted quickly across to an asphalt heater approximately 80 feet away, when the burner flame ignited the gas which flashed back to the drain pipe and continued to burn fiercely at the end of the pipe. Due to the flash back and ensuing fire four persons, two plant operators and two fitters were severely burnt, the two plant operators subsequently dying from the effects of the burns.

The conflagration was stopped by shutting the valve nearest the vessel by means of the chain fitted to a chain wheel on the spindle. The operator who shut this valve said it was full open. There is some doubt as to how much the bottom valve was open, but it seems to have been open approximately two turns. Whether it had been opened further than that and the operator was closing it when the flash back occurred is not known. It is possible it was opened wider as there may have been some lumps of asphalt still lodged in the pipe even after cleaning. The cock at the bottom of the drain line was found to be full open and immoveable after the fire. It is possible that the fire caused this cock to seize but I feel that it was probably seized prior to the fire as cocks notoriously do if not checked and worked at regular short intervals. In support of this conclusion the handle for the cock was found some distance from the cock, fitted with a piece of pipe for leverage, and the pipe had quite a pronounced bend in it.

From investigation the following factors emerged:—

(1) The light wind blowing that day was insufficient to disperse the gas but of sufficient force and direction to carry it rapidly to the flame of the asphalt heater. The time taken for the gas to reach the flame was quoted as 6 to 7 seconds.

(2) If the plant operator doing the draining realised that far too much gas was escaping he was probably trying to shut the valve. Had the handle been on the cock and the cock easily moveable he could have shut the gas off with a 90° movement of the handle in one motion, much quicker than he could close the valve. Presumably the cock was installed on the line for the purpose of effecting a quick shut off in such an emergency.

B.

This incident which also resulted in a fatality is similar to the foregoing in that no boiler or pressure vessel was directly involved but a line and valve attached to it, and also there was an escape of gas, but this time ammonia.

The plant involved in this mishap was an aqueous ammonia storage vessel attached to an ammonial distilling plant at a fertiliser works. At the time of the accident an overhaul of the pipe lines and valves of the distillation plant was in progress. Prior to work commencing it was usual to steam purge all lines through the complete working cycle with only the stop valve on the storage vessel shut. The lines were then left with all valves open and open to atmosphere through a gauge glass drain. This routine had been followed and the lines left open for four days with the exception that the last control valve in the system before the storage vessel main stop, had been left closed. This appears to have been a precaution against leakage of the main stop.

It appears that when the victim, a fitter, proceeded to dismantle the control valve by taking off the cover there was an escape of ammonia which hit him in the face. The inhalation of the ammonia caused confluent broncho pneumonia and his death several days later.

Investigations as to how the ammonia came to be present, included checking the length of pipe between the control valve and the stop valve for any blockage which could have trapped the gas, but the pipe proved quite clean. However it was noticed that there was a smell of ammonia round the stop valve, indicating a possible leak. The pipe and control valve were replaced with a pressure gauge in the line and the control valve was again shut. Over a period of approximately 24 hours the pressure in this section of line built up to 38 p.s.i. The pressure in the storage vessel was 122 p.s.i. Ambient temperatures were considerably lower in this period than in the days prior to the mishap. It therefore seems safe to assume that the presence of gas in the line was due to the storage vessel main stop leaking. From the inspection of the control valve cover and spindle it is considered that this valve was in the closed position when the cover was removed.

This accident points up the inherent dangers of ammonia in the gaseous state but particularly in the aqueous condition where a small amount of liquid expands into a considerable quantity of gas Emphasis is also given to the folly of removing any valve cover without first opening the valve to make sure the line is empty and there is no pressure build up.

C.

This concerns two similar type internally fired multi-tubular package boilers and the defects found once again attributed to excessive steam draw-off when sudden heavy demands are made on the boiler. Comment has been made previously on this type of installation and defects.

In the first instance the boiler supplies steam to large autoclaves in a brick manufacturing industry. It was found that the autoclaves were filled with steam at an excessive rate so that the pressure in the boiler dropped rapidly from 210 p.s.i. to 125 p.s.i. No restriction or control was fitted to regulate the flow of steam and it is considered that as the boiler automatically went on to high fire there was turbulence in the water, steam insulation of heating surfaces resulting in overheating and damage to the tubes and tube place in the hottest areas.

The second instance is a boiler in a tyre manufacturing concern where again there are heavy peak loadings due to filling vulcanisers without control of the steam draw. This boiler is building up a history of leaking tubes and unless some restriction is placed on the steam flow I feel it is only a matter of time before the tube plate is adversely affected.

These two examples highlight the need for careful investigation of the steam requirements, not only taken as an average but with careful note of peak demands, so that a boiler of sufficient capacity to cope, without forcing, is installed. It appears that the days of over designed under rated boilers of large steam and water capacity are gone. There is therefore very little margin for under estimation of load requirements to cover up errors in load assessments.

D.

A defect in an autoclave considered worth noting and the method of repair is the subject of this case. The autoclave concerned was a jacketed vessel 36in. x 24in. section x 61 in. long and seven years old. The inner shell was 5/16 in. t.m.s. plate stainless steel clad the outer 5/16 in. mild steel.

When this vessel was inspected cracking was found adjacent to the welds attaching 2-1 in. x ¼ in. thick stainless steel carriage runners to the bottom of the inner shell. The longitudinal weld in the top of the inner shell also appeared to be cracked in several places. The autoclave was removed from service and stripped down for the inspection. A second inspection when the runners had been chipped off showed that the stainless steel cladding had cracked and was lifting away from the parent metal. This was also the case with the longitudinal seam. The upper surfaces of the inner showed considerable corrosion and pitting. The internal surfaces were cleaned up with a buff and ground off where necessary in preparation for fitting a false back and sides in ⅛ in. thick stainless steel. The sides were fitted in four pieces giving four long seams, with penetration through to the original material on the middle of each side. The back was fitted by inserting and fillet welding to the new sides.

This vessel is used for sterilising bottles of saline solution and breakage in the process is quite frequent. It is thought that the corrosion and cracking in the inner was due to lack of or insufficient cleaning after use and particularly after breakages. Specific instructions concerning the necessity for this were given and after six months operation it appears to be in satisfactory condition.

Section 3.

INSPECTION OF MACHINERY.

(See Returns Nos. 4, 5 and 6.)

At the expiration of the year 52,479 groups of machinery were in the register. There is an increase of 2,109 groups compared with the figures for the previous year. Lift figures reveal an increase of 80 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, 1965.

	Districts Worked from Perth	Districts Worked from Kalgoorlie	Totals 1965	Totals 1964
Number of groups driven by Steam Engines	117	372	489	485
Number of Groups driven by Oil Engines	3,744	1,029	4,773	4,319
Number of Groups driven by Other Power	116	199	315	301
Number of Groups driven by Electric Motor....	43,001	3,901	46,902	45,265
Totals	46,978	5,501	52,479	50,370

RETURN No. 5.

Showing Operations in Proclaimed Districts during year ended 31st December, 1965. (Machinery only.)

——	Districts Worked from Perth	Districts Worked from Kalgoorlie	Totals 1965	Totals 1964
Total Registrations Useful Machinery	46,978	5,501	52,479	50,370
Total Inspections made	26,460	3,981	30,441	32,136
Certificates (Bearing Fees)	5,410	530	5,940	6,633
Notices issued (Machinery Dangerous)	534	34	568	732

RETURN No. 6.

Showing Classification of Lifts on 31st December, 1965.

Types	How Driven	Totals 1965	Totals 1964
Passenger	Electrically Driven	357	325
Passenger	Electric Hydraulic Driven	13	....
Goods	Electrically Driven	124	116
Goods	Electric Hydraulic Driven	9	13
Service	Electrically Driven	136	113
Service	Electric Hydraulic Driven	3	1
Escalators	Electrically Driven	39	33
		681	601

ACCIDENTS TO MACHINERY.

During this year accidents to machinery not involving persons, fortunately seem to be confined mainly to the mobile crane field as was the case last year. The causes vary but overloading either knowingly or unknowingly, poor maintenance and in some of back yard manufacture poor design and construction are fairly common. Several mishaps are dealt with briefly below.

Case A and B.

This crane was being used on a construction job where hollow piles with a bottom coverplate were driven into the ground formed by the spoil dredged out of a river. When these piles are at full depth they are filled with clean sand. The piles are then pulled, the bottom cover plate being loose and attached to the bottom of the pile by a chain at one side, falls away and comes up with the tubular pile. This leaves a column of clean sand in the dredged material. The object of this project is to stabilise the dredge material by allowing the water trapped in it to be pushed to the surface through these vertical sand columns. To increase the pressure and therefore the compression on the spoil many tons of sand are heaped over the area.

The pile driving and sand filling did not present any great problems but the pulling of the piles did. As can be readily understood there was quite a variation in the hardness and other characteristics of the material into which the piles were driven. When pulling was in progress some piles come away easily, others are more difficult. With the difficult ones once the load was taken it became impossible for the crane operator to know what load was being lifted and the tendency was to overload the machine till the back lifted clear of the round. As a result of these operations one jib failed and on another machine the turntable was severely damaged when the plate tore at the joint between it and the chasis.

The pulling of piles of any kind, including sheet piling can be particularly severe on cranes unless it is carefully watched that the crane has plenty of reserve capacity. The solution of course is to fit load indicators for this type of work.

CASE C.

This concerns a mobile jib crane which had been left unattended for the night with 100 ft. of jib and fly jib on. The jib was pointing towards the building on which it had been working and the slewing lock was in. In the early hours of the next morning the jib crashed to the ground, fortunately falling sideways and laid along the foot path. No one was injured.

Investigation showed that one of the jib pivot pins came out allowing the jib to fall sideways. During the night in question a heavy wind blew up so that if the pin was almost out the movement of the jib in the wind would probably jar it out the rest of the way. When the pin was looked at it appeared that the pin had seized in the support bracket and instead of turning with the forked jib end had turned in it and damaged the pin end and keeper plate so that it was no longer locked in position. It was stated that noises had been heard from this pivot point but apparently no thorough investigation had been made.

Section 4.

PROSECUTIONS FOR BREACHES OF THE ACT.

There are no prosecutions to report.

Section 5.

ACCIDENTS TO PERSONS.

Return 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.

The overall total of occurrences shown in the two returns numbers 110.

During the year two fatalities occurred involving lifting machinery.

CASE A.

This was a fatal accident involving an excavator working in a quarry loading limestone into trucks at night. The accident occurred when a truck had been backed into position for loading. The excavator buck had been filled and was suspended at a point where the truck being backed under it the load could be dropped into the truck body. As the truck was positioned the excavator driver states that he let go the slew brake to operate the bucket trip lever with two hands. The machine then started to slew towards the cab of the truck in which the driver was still seated. When he saw this the excavator driver grabbed the slew and hoist levers and attempted to slew back and at the same time hoist the bucket. He was successful in the latter movement and overhoisted the bucket. There was a loud crack and the bucket dropped in the truck cab, crushed it and the ununfortunate driver who was still in the cab.

Investigations showed that the hoist rope had parted at a point approximately 8 ft. from the anchor point on the jib where it passed over the head sheave. The rope was only a week old and inspection showed it to be in excellent condition. It was eventually deducted that the buck had been overhoisted to such an extent that the block on the bucket and the head sheaves had been jammed together so that the load was taken out of the luff ropes and in effect the hoist rope was being used to luff the jib and load. Since calculations on this condition show that the load in the hoist rope is increased six fold by this action, factor of safety become 1.7 and with impact would be even less. It is also considered that at the point of failure the rope would be unevenly loaded so that there is a strong possibility of some strands breaking before others. This was demonstrated when the above conditions were induced experimetally and even though the strain was taken slowly with no load in the bucket, one strand parted.

It is possible that the rope was already damaged before the accident as the driver being new to the machine, stated he had overhoisted on a few occasions that day. It is possible therefore that one or more strands had already parted.

This mishap reveals a hazard not readily apparent and shows the danger of overhoisting. If overhoisting does accidentally occur then the rope at the head sheave should be immediately checked for possible damage.

CASE B.

This accident which unfortunately was also fatal involves a monorail hoist which was used to raise and lower goods between the ground and first floors of a warehouse. To reach the first floor goods were hoisted through a large square opening fitted with a handrail in that floor. At the time of the accident a case slung by chain round it had been lifted on the 1st floor and the hoist was being pulled along the monorail and over the floor opening to lower it to the ground floor.

In order to move the hoist load over to the opening a rope was permanently attached to the hoist and it was then necessary to walk round to the side of the opening and heave on the rope to pull the loaded hoist along the monorail. This method was effective but tends to cause the load to swing from side to side and also fore and aft as the hoist trolley wheels move jerkily. Therefore the movement of the load is rather uncontrolled. As the load approached the handrails it appears that it was low or the case, being suspended at the centre, see-sawed so that one end struck one of the posts supporting the handrails. This set the case swinging so much that the lifting tackle slipped off the hook and the case fell through the floor opening. Unfortunately at this moment the victim walked out from under the first floor and was hit by the case as it fell.

Three main points emerged from this mishap—

1. The care exercised by the hoist operator should have been such that the box did not hit the handrail.
2. The hoist hook should have been moused or the slinging chain made secure on the hook so that it could not jump off.
3. Persons should not be permitted to walk in areas under hoisted loads.

CASE C.

This accident involves a mobile crane of five ton capacity which was on hire and being used to lift band screens from a sea water inlet at a powerhouse. These bandscreens are installed to prevent the entry of seaweed and other marine growth into the cooling systems of the generating plant. Therefore a considerable section of the screening mechanism is immersed in sea water.

The top and heavier section had been lifted out and the crane was attached to the bottom section which was almost fully submerged and estimated to weigh one ton. The crane was hooked onto the load and the strain taken up but the screen failed to move. Work was stopped but the tension was maintained on the crane while a discussion was taking place to consider re-positioning the slings. At this moment the jib fractured through the four main chords at approximately 15 ft. from the top end and crashed down. One of the men working on the job was standing almost directly under the jib but whether he was struck on the leg by the broken section or instinctively threw himself sideways but had his foot trapped in the screen framework, is not known. Unfortunately he sustained such severe crushing injuries to his ankle that his foot had to be amputated.

From investigations the crane was working at a radius and permissible load satisfactory for lifting the 1 ton load. However it appears that due to marine growth or eccentricity in the guides the screen jammed, thus giving an unknown load which was beyond the jib strength. It is estimated that a load of approximately 5 tons would have been necessary to produce failure of the jib. Examination of the jib did not show any fault in the material and a metallurgical examination indicated no abnormalities nor reasons to suspect metal fatigue.

From the foregoing it appears that the crane was grossly overloaded but without the driver or anyone else realising it. This is an ever present hazard where the object to be lifted can become jammed due either to foreign bodies or corrosion entering clearance spaces particularly where sea water is present. This creates the hazard of an unknown load being applied to the machine.

Another point emphasised by this mishap is the danger of standing anywhere under the jib under these circumstances.

Return No. 7.

Showing Number of Serious Accidents, Both Fatal and Non-fatal which Occurred in Proclaimed Districts during the Year Ended, 31st December, 1965.

"F" Denotes Fatal.

Industry	Circular Saw	Spindle Moulder (Shaper)	Buzzer (Planer)	Band Saw	Chain Drive	Winch	Belts and Shafting	Gearing	Conveyor (Belt, Slat)	Hoist	Mobile Crane	Overhead Elec. Travel. Crane	Dough Moulder	Abrasive Wheels and Belts	Tyre Building M/c	Lathe (Metal)	Guillotine (Metal)	Press (Metal)	Press (Other)	Milling Machine	Rolls	Teasing M/c	Wool Processing M/c	Mincer	Printing M/c	Mixing M/c	Steam Jacketed Pan	Tyre Buff	N.H.3 Pipelines and Valves	Mine Shaft	Winding Engine	Propane Work Drum	Totals of Industry
Woodworking and Furniture	6	3	7	....	....	....	....	....	1	....	1	....	....	....	....	....	....	....	....	....	....	....	....	....	1	....	....	....	....	....	....	....	19
Metal Working and Engineering	1	1	....	1	1	....	....	....	1	....	1	1	....	4	....	1	1	5	....	1	5	....	....	....	....	3	....	....	....	....	....	....	27
Printing and Allied Industries	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	1	....	....	....	....	....	....	....	1
Food and Drink Processing	....	....	....	....	....	....	1	....	1	....	....	....	1	....	....	....	....	....	....	....	2	....	....	2	1	1	1	....	....	....	....	....	10
Building Materials and Building	....	....	....	....	....	1	....	....	1	1	1	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	4
Mining	2	....	....	....	....	....	....	....	....	....	2 (1F)	....	....	2	....	....	....	1	....	....	....	....	....	....	....	....	....	....	....	1 (F)	1	....	9 (2F)
Wool Processing	....	....	....	....	....	....	....	1	....	....	....	....	....	....	....	....	....	....	1	....	....	1	2	....	....	....	....	....	....	....	....	....	5
Fertiliser Manufacture	1	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	1 (F)	....	....	....	2 (1F)
Other	....	....	....	....	....	....	1	....	....	1 (F)	1	....	....	....	1	....	....	....	....	....	....	....	....	....	1	....	....	1	....	....	....	1 (F)	7 (2F)
Totals per Type of Machine	10	4	7	1	1	1	2	1	4	2 (1F)	6 (1F)	1	1	6	1	1	1	6	1	1	7	1	2	2	4	4	1	1	1	1	1	1	84 (5F)

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, 1965.

Industry	Circular Saw	Thicknesser	Band Saw	Abrasive Wheel and Belts	Belts and Shafting	Clawing M/c	Conveyor (Belt Slat)	Overhead Electric Travelling Crane	Shaping M/c (Metal)	Polishing Buff	Lathe (Metal)	Press (Metal)	Press (Other)	Rolls	Mincer	Wool Processing M/c	Tyre Building M/c	Totals per Industry
Woodworking and Furniture	1	1	1	....	....	1	....	....	....	....	....	....	....	....	....	....	....	4
Metalworking and Engineering	1	....	....	3	....	....	....	2	1	1	1	1	....	....	....	....	....	10
Printing and Allied Industries	....	....	....	....	....	....	....	....	....	....	....	....	....	1	....	....	....	1
Food and Drink Processing	....	....	1	....	1	....	1	....	....	....	....	....	....	....	1	....	....	4
Wool Processing	....	....	....	....	....	....	1	....	....	....	....	....	1	....	....	2	....	4
Other	....	....	....	....	....	....	1	....	....	....	1	....	....	....	....	....	1	3
Totals per type of machine	2	1	2	3	1	1	3	2	1	1	2	1	1	1	1	2	1	26

Section 6.

EXAMINATION OF ENGINE DRIVERS, CRANE DRIVERS AND BOILER ATTENDANTS.

During the year the Board of Examiners granted 114 Engine Drivers', 336 Crane Drivers' and 68 Boiler Attendants' Certificates.

Compared with the previous year these figures show an increase of 12, increase of 58, and a decrease of 22 respectively in the number of certificates granted.

This year has again seen an increase in the numbers of certificates issued mainly in the Crane Driver field. This necessitated the Board spending more time on examinations both in the country and metropolitan area, but with pressure of normal duties also increased it becomes more difficult.

Section 7.

STAFF AND GENERAL.

I regret that I have to report that once again the year has been difficult and frustrating both to myself and the inspectorial staff. So many matters come up which require thought, attention, discussion and follow up action but they are either rushed or lost in the next day's activities. It amazes me that the branch functions as efficiently as it does when all work is done under pressure due to increased volume of work and shortage of staff.

During the year Mr. Smith's transfer to the Public Service Commissioner's Office was confirmed and Mr. Doohan filled the vacant item. In addition permission was granted by the P.S.C. to employ two temporary Inspectors. These two positions have been advertised. On the clerical side there has been no alteration in numbers of staff but increased work in the inspection side has increased the load on them. In addition the large number of Engine Drivers' applications has made the position of Registrar and Secretary to the Board of Examiners impossible for one man to cope with and the two positions will require separation.

The year has seen further growth in activity particularly in the opening up of iron ore mining in the North West and near Morawa, and extension of activity at Koolyanobbing. As usual the construction period is the time when large numbers of men and machines are employed in very rough conditions which require more attention from this Branch at this stage than when they are in production.

Expansion continues with the building of new plant at C.S.B.P., the commencement of the blast furnace construction at Kwinana. Civil construction connected with the standard gauge railway and new factories and buildings has increased. Nobody denies that the work of this Branch has and is increasing but pleas for extra staff take months to come to fruition by which time further staff is required.

With the erection of new factory and store premises so the number of overhead electric crane installations increases. Manual handling is avoided as much as possible and each building has at least one overhead crane and generally more. The same increases apply to new office and residential buildings and the number of lifts. During the year eighty new lifts were erected.

The remarks I made last year concerning the pressure on staff still apply and I feel that some of the sickness among some members could be partly attributable to overwork. However as usual, all members of the staff both inspectorial and clerical have responded willingly to demands made on them. For another year of co-operation and unstinting service I wish to thank them.

I would also like to thank the Police Department for continued co-operation in reporting accidents, and assistance given in investigations where we were associated.

In conclusion on behalf of all members of this Branch our thanks for assistance given 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 1965 Compared with 1964.

——		Numbers 1965	Granted 1964
Winding	Competency including Certificates issued under Reg. 40 and Section 60 of the Act	7	12
First Class	" " " " " Reg. 40 and 45 and Sections 60 and 63 of the Act	36	21
Second Class	" " " " " Reg. 40 and Section 60 of the Act	12	15
Third Class	" " " " " Reg. 40 and 45 and Sections 60 and 63 of the Act	11	14
Locomotive and Traction	" " " " " Reg. 40 and Section 60 of the Act	....	1
Internal Combustion	" " " " " Reg. 40 and Section 60 of the Act	42	32
Crane and Hoist	" " " " " Reg. 40 and Section 60 of the Act	336	278
Boiler Attendant	" " " " " Reg. 50 and Section 60 of the Act	68	90
Diesel Loco.—			
Class A	" " " " " Reg. 40 and Sections 53 and 56 of the Act	4	1
Class B	" " " " " Reg. 40 and Sections 53 and 56 of the Act	2	7
Interim Certificates	.... Section 61	3	....
Copies	....	11	13
		532	484

RETURN No. 9.

Revenue and Expenditure for Year Ended 31st December, 1965. and Comparison with Preceding Year.

	Revenue	
	1965	1964
	£ s. d.	£ s. d.
Fees from Boiler Inspections	6,525 9 6	6,016 5 2
Fees from Machinery Inspections	8,977 2 3	9,822 10 5
Fees from Engine Drivers	1,080 11 0	939 1 3
Incidentals	244 5 11	273 19 10
Total	£16,827 8 8	£17,051 16 8

Decrease in Revenue compared with 1964—£224 8s. 0d.

	Expenditure	
	1965	1964
	£ s. d.	£ s. d.
Salaries	44,210 10 11	42,487 12 6
Incidentals	8,975 0 4	9,052 17 2
Engine Drivers' Examinations	172 9 1	127 0 9
Totals	£53,358 0 4	£51,667 10 5

Increase in Expenditure compared with 1964—£1,690 9s. 11d.

RETURN No. 10.

Showing Distances Travelled, Number Inspections Made and Average Miles Travelled for Inspections for the Year Ended 31st December, 1965.

	Road Miles	Air Miles	Rail Miles	Water Miles	Collective Mileage all Transport Services	Number of Inspections	Average Miles per Inspection
Districts operated from Perth	123,084	1,700	*Nil*	*Nil*	124,784	32,842	3·80
Comparison with 1964	Inc. 17,727	Inc. 340	*Nil*	*Nil*	Inc. 18,067	Dec. 621	Inc. 0·61
Districts operated from Boulder	14,535	*Nil*	*Nil*	*Nil*	14,535	4,338	3·35
Comparison with 1964	Dec. 2,219	*Nil*	*Nil*	*Nil*	Dec. 2,219	Dec. 381	Dec. 0·20
Totals	137,619	1,700	*Nil*	*Nil*	139,319	37,180	3·75
Comparison with 1964	Inc. 15,508	Inc. 340	*Nil*	*Nil*	Inc. 15,848	Dec. 1,002	Inc. 0·52

Note Abbreviations :—Inc. = Increase ; Dec. = Decrease.

Average Miles per inspection all districts, 1965 .... 3·75
Average Miles per inspection all districts, 1964 .... 3·23
Increase per inspection compared with 1964 .... Inc. 0·52

RETURN No. 11.

Engine Drivers' and Boiler Attendants' Board Matters. 1965.

Examinations in—

Perth, 4.
Kalgoorlie, 2.
Bunbury, 1.
Collie, 1.
Special Examinations, 97.
South West, 3.
Esperance, 1.
Geraldton, 2.
North West Ports, 1.
Morawa, 1.

Examinations were held at all advertised centres.

84 days on actual examinations by travelling Board.
45 days spent in Perth dealing with applications for competency certificates, examination papers and enquiries, etc.
77 days spent in travelling and looking into matters connected with engine drivers and boiler attendants.
658 applications received.
532 certificates granted.
Revenue £1,080 11s. 0d.

DIVISION VII

Government Chemical Laboratories Annual Report—1965

Under Secretary for Mines:

I have the honour to present to the Honourable Minister for Mines a summarised Annual Report on the operations of the Government Chemical Laboratories for the year ended 31st December, 1965.

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) as follows:—

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.S., A.R.A.C.I.

Agriculture and Water Supply Division—H. C. Hughes, B.Sc., A.R.A.C.I., Divisional Chief.

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., C.Eng., 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, 1965, the staff of the Laboratories numbered 92, being—

Professional	55
General	24
Clerical	8
Wages	5

The year 1965 repeated the unusual feature of 1963 of not being difficult to obtain staff. We did however still have the problem of several years past of not having the physical space to accommodate a required increase in staff necessitated by the increased volume of work to be done. Now that extensions to our buildings are nearing completion it is possible and essential to increase our staff markedly to enable us to undertake the work required.

The close association of these Laboratories with other Government Departments, and with kindred associations was maintained during 1965 and various members of the staff are members of the following Committees:—

Air Pollution Control Council.
Australian Coal Industry Research Laboratories Limited—Board of Management.
Commonwealth Scientific and Industrial Research Organisation State Committee.
Food and Drugs Advisory Committee.
National Association of Testing Authorities State Committee.
National Coal Research Advisory Committee.
Oils Committee of the Government Tender Board.
Paints Advisory Committee of the Government Tender Board.
Pesticides Registration Committee.
Phytochemical and Toxic Plants Committee.
Poisons Advisory Committee.
Rivers and Waters Technical Advisory Committee.
Scientific Advisory Committee under the Clean Air Act.
Swan River Conservation Board.
Veterinary Medicines Advisory Committee.
Water Purity Advisory Committee.

Most of these Committees are very active and meet regularly and occupy considerable time of the officers concerned, not only for meetings, but also for inspections, preparation of information and analyses of samples. This has been particularly so for (a) the Australian Coal Industry Research Laboratories Limited and (b) the National Coal Research Advisory Committee both of which were established in 1965 and required a large amount of time and attention in the formative stages, (c) the Poisons Advisory Committee which came into operation in 1965 and occupied considerable time and thought for the drafting and gazetting of Regulations under the Poisons Act. The Pesticides Registration Committee dealt with 130 applications for registration of new pesticide formulations. The total number of applications considered by this Committee to 31st December, 1965 is 1,789. A matter of great concern to this Committee is the poisonous nature of most of the newer pesticides, especially as many of them can be absorbed through the skin. The Committee has maintained its past policy of on occasions refusing registration of a pesticide as being too hazardous to health; placing an upper limit on the concentration of active ingredient in the formulation to be distributed; or has restricted distribution to commercial pest exterminators. The Veterinary Medicines Advisory Committee dealt with 902 applications, being 799 renewals, 73 new registrations, 4 changes of formula or claim, 8 deferred, 13 not required to be registered and 5 rejections. For the Swan River Conservation Board we analysed 109 samples of river water and 23 samples of effluents being discharged into the river.

Membership of the National Coal Research Advisory Committee and the Board of Management of the Australian Coal Industries Research Laboratories Limited has necessitated several journeys to Sydney for Mr. Donnelly and Dr. Uusna.

Equipment.

The only major items of equipment obtained during the year were a Unicam SP800A double beam ultraviolet and visible recording spectrophotometer and a high tension electrostatic separator.

Accommodation

Although it is pleasing to record that extensions to these Laboratories are being built it is extremely disappointing that construction is so slow. Stage 1, commenced in October, 1962 is now operational, but of Stage 2 only a very small portion is yet in use. The construction of stage 3 has commenced but progress in 1965 was such that there was no real net increase in laboratory space available. It is now nearly 7 years since my first formal request for additional accommodation and more than 3 years since construction commenced but the effective addition to our working space is very small. This is the more unfortunate because of the increasing demands on these Laboratories as discussed later, that the number of samples not completed on 31st December, 1965 is nearly twice the number as at 31st December, 1964.

During the year a new workshop was constructed and equipped at the Engineering Chemistry Division.

Investigation.

In my Annual Reports for 1960 and 1961 I referred to pollution of underground water with chlorophenols and 2,4-D. Analyses since then have shown that these contaminants still persist. A matter of great interest has been that though the soil concerned is sand the pollution has been confined to a very narrow field and from the wells and bores available for testing, the pollution has not spread laterally in the 6 years it has been under observation. During 1965 it was possible to drill test bores both across and along the line of movement of the contaminants. This has not only confirmed that the pollution is confined to a narrow strip horizontally but is also restricted to a narrow strip vertically.

General.

The total number of registrations in 1965 was 3,616, only a very slight increase on the 3,551 of 1964 but the number of samples received was 14,816 an increase of 14 per cent. over the number received in 1964 (12,962). Since we have not been able to increase our staff commensurately, nor indeed at the same rate as the Public Service generally, nor in conformity with increased industrial and mining activity in the State the number of "samples in hand" (samples received but not reported) at the end of 1965 was nearly double the number a year earlier; 3,569 at the end of 1965 compared with 1,898 at the end of 1964. This illustrates the demand, the increasing demand, on these Laboratories by other Government Departments and the public but until increased accommodation and staff are available it will not be possible for us to give the service we can and should give. It is expected that 1966 will again show a marked increase in the number of samples received, indeed the Traffic Act Amendment Act (No. 3) of 1965 is expected to increase by several thousand the number of blood samples to be analysed for alcohol.

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 variation in the amount of work associated with different 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, industrial firms and the general public; attendance at Courts; visits to factories and so on.

The samples received during 1965 were allocated to the various Divisions of these Laboratories according to the specialised work undertaken by each Division, Table 1.

Table 1.

SOURCE AND ALLOCATION OF SAMPLES RECEIVED DURING 1965.

Source	Division							
	Agriculture	Engineering Chemistry	Food and Drug	Fuel Technology	Industrial Chemistry	Mineralogy	Physicist and Pyrometry Officer	Total
State—								
Agricultural Department	4,285	....	700	....	4	4	1	4,994
Fire Brigades Board	1	....	1	....	....	....	....	2
Fisheries Department	1	....	1	....	....	2	....	4
Forests Department	....	....	....	....	2	....	....	2
Fremantle Port Authority	9	....	....	....	....	....	....	9
Hospitals	1	....	73	1	....	....	....	75
Industrial Development Department	....	....	1	....	....	4	6	11
Labour Department	....	....	51	....	....	....	....	51
Lands and Surveys Department	8	....	....	....	....	....	....	8
Local Authorities	....	....	4	....	....	....	....	4
Main Roads Department	7	....	....	....	3	7	....	17
Medical Department	7	....	....	....	....	....	1	8
Metropolitan Water Supply Board	211	....	1	6	....	20	....	238
Milk Board	....	....	579	....	....	....	....	579
Mines Department	423	1	91	91	19	659	21	1,305
National Safety Council	2	....	....	....	....	....	....	2
Native Welfare Department	4	....	....	....	....	4	....	8
Police Department	....	....	1,215	....	....	4	....	1,219
Public Health Department	18	....	826	1	1	30	....	376
Public Service Commissioner	....	....	1	....	....	....	....	1
Public Works Department	265	1	151	3	31	26	3	480
State Housing Commission	....	....	....	1	13	5	....	19
Swan River Conservation Board	....	....	133	....	....	....	....	133
Treasury Department	5	....	70	....	....	....	....	75
CoUniversity of Western Australia	3	....	....	....	....	....	....	3
W.A. Government Railways	1	....	13	....	....	....	....	14
mmonwealth—								
Air Department	3	....	39	....	....	....	....	42
Civil Aviation Department	3	....	2	....	....	2	....	7
Commonwealth Scientific and Industrial Research Organisation	3	....	....	....	....	....	....	3
Navy Department	....	....	1	....	....	....	....	1
Police Department	....	....	1	....	....	....	....	1
Postmaster General's Department	....	....	....	....	....	2	....	2
Shipping Department	....	....	1	....	....	....	....	1
Public—								
Free	11	....	4	8	....	3,210	2	3,235
Pay	940	6	152	26	9	741	10	1,884
United States Navy	....	....	....	....	....	118	....	118
	6,211	8	3,611	137	82	4,838	44	14,931

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 ability and experience 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 in Table 1 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 6 separate Divisions. 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 specialist in another Division. To assist in this we introduced in 1965 talks by senior chemists to groups of staff from other Divisions, talks on the work done, the facilities available and the capacity of those facilities.

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 without charge for other State 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 1965 with 1964 there were some marked alterations in the numbers of various types of samples received.

These were:—

	1964	1965
Marked increase	1964	1965
Arsenic (mineralogy)	—	2077
Clay	26	113
Grass	84	288
Iron ore	68	232
Lead ore	24	101
Mineral identification	463	606
Oats	110	204
Pesticides	175	337
Tin ore	86	177
Wheat	565	1039
Marked decrease	1964	1965
Clover	1457	941
Gold, ore, tailing, umpire	542	378
Pasture, mixed	676	130
Soils	864	503

There were also two appreciable changes in the sources from which samples were received. In 1965 the number of samples from the Mines Department increased by more than 20 per cent. and from the public by some 70 per cent. This latter increase was largely due to a geo-chemical survey for a mining company.

L. W. SAMUEL,
Director.

AGRICULTURE AND WATER SUPPLY DIVISION.

The year 1965 was remarkable for the almost complete change in senior staff. The promotion, after more than seven fruitful years as Divisional Chief, of Mr. Gorman to be Deputy Director, and the resignation of Mr. Broadbent to go overseas after almost as lengthy a period as Second-in-Charge, resulted in the appointments of Messrs, Hughes and Platell, formerly Grade 1 Chemists and Research Officers to fill the vacancies.

Mr. Gorman had supervised many changes in the Division, and the opportunity was taken by the staff to wish him well in his new responsibilities.

Towards the end of the year Mr. Jago joined us from the Department of Agriculture and Mr. Jack was promoted, these officers now holding the Grade 1 positions. Additional assistance was provided by the transfer of two officers from other divisions pending the creation of more staff positions to help with the large amount of work in hand.

The hope expressed in last year's Annual Report for the early completion of building extensions was not fulfilled, and it was not until December 13th that two rooms only became available, this barely compensating for the space lost in the necessary alterations involved in joining the two sections.

In 1965 there was a decrease of 10 per cent. in the number of samples received compared with 1964. This decrease was attributed to the decline in the number of pastures, fodders and soils while the work on animal nutrition and cereals doubled. There was also an increase in the samples received under the Fertilisers Act.

The number, type and source of the samples received in 1965 are listed in Table 2.

Table 2.

AGRICULTURE AND WATER SUPPLY DIVISION.

	Agriculture Department	Metropolitan Water Supply	Mines Department	Public		Public Health Department	Public Works Department	Other Government Departments	Other	Total
				Free	Pay					
Animal—										
Hair, bovine	12	....	....	....	....	....	....	....	....	12
Liver	107	....	....	....	....	....	....	....	....	107
Ovaries, bovine	19	....	....	....	....	....	....	....	....	19
Various	14	....	....	....	....	2	....	....	....	16
Cereals—										
Oat—										
Grain	53	....	....	....	....	....	....	....	....	53
Leaves	50	....	....	....	....	....	....	....	....	50
Straw and Grain	70	....	....	....	....	....	....	....	....	70
Tops and Roots	16	....	....	....	....	....	....	....	....	16
Various	15	....	....	....	5	....	....	....	....	20
Wheat—										
Flour	1	....	....	....	....	....	....	....	....	1
Grain	113	....	....	....	....	....	....	....	....	113
Plant	356	....	....	....	....	....	....	....	....	356
Tops	569	....	....	....	....	....	....	....	....	569
Various	5	....	....	....	....	....	....	....	....	5
Fertiliser—										
Act	77	....	....	....	....	....	....	....	....	77
Fertiliser	33	....	....	....	9	....	....	....	....	42
Guano	....	....	....	....	10	....	....	....	....	10
Lime	....	....	....	....	12	....	....	....	....	12
Rock phosphate	5	....	....	....	12	....	....	....	....	17
Superphosphate	35	....	....	....	1	....	....	....	....	36
Various	4	2	....	....	1	4	....	....	....	11
Horticulture—										
Apple—										
Fruit	5	....	....	....	....	....	....	....	....	5
Leaves	169	....	....	....	....	....	....	....	....	169
Cauliflower leaves	10	....	....	....	....	....	....	....	....	10
Orange leaves	74	....	....	....	....	....	....	....	....	74
Pear—										
Fruit	36	....	....	....	....	....	....	....	....	36
Leaves	3	....	....	....	....	....	....	....	....	3
Various	20	....	....	....	....	....	....	....	....	20
Miscellaneous—										
Currants, dried	28	....	....	....	....	....	....	....	....	28
Linseed	353	....	....	....	....	....	....	....	....	353
Minerals	....	....	38	1	....	....	....	....	....	39
Oil seeds	33	....	....	....	....	....	....	....	....	33
Plant material	42	....	....	....	....	....	....	....	....	42
Safflower	49	....	....	....	....	....	....	....	....	49
Various	15	1	9	....	22	....	8	5	3	63
Pastures and Fodders—										
Clover	941	....	....	....	....	....	....	....	....	941
Grass	288	....	....	....	....	....	....	....	....	288
Lucerne	10	....	....	....	....	....	....	....	....	10
Pasture	130	....	....	....	....	....	....	....	....	130
Samphire	49	....	....	....	....	....	....	....	....	49
Various	37	....	....	....	15	....	....	....	....	52
Soil	432	....	....	....	69	....	2	....	....	503
Water	7	208	376	10	785	12	254	20	30	1,702
Total	4,285	211	423	11	941	18	264	25	33	6,211

Soils

1. Molybdenum.—Responses in yield by either cereals or legumes to the application of molybdenum fertiliser, the response of wheat at Bodallin being the first such recorded response in Australia, lead to the soils from the sites involved being examined for a number of factors.

The virgin soil at Bodallin was found to contain 0.75, 0.77 and 0.90 parts per million of molybdenum at the 0-3 in., 3-6 in. and 6-12 in. levels.

From an area at Wyalkatchem the total molybdenum content was uniformly 1.1 p.p.m. to a depth of 24 in., at Gutha it increased from 0.8 p.p.m. in the top 5 in. to 1.4 p.p.m. at 18 in. At South Borden, Wilroy and North Merredin the figures were of the same order. However at Forrestonia, Eneabba, Binu and East Northampton the molybdenum content ranged downwards from 0.6 to 0.1 p.p.m. for soils which were more sandy.

2. Samples representative of plots at Wongan Hills Research Station were submitted to mechanical analysis. These were under their first year of clover and will be examined in subsequent years to follow the effect of various cultivation practices in clover-wheat rotation. Results for these preliminary samples showed a variation of from 79 to 84 per cent sand, with 15 to 10 per cent clay.

3. Replicates of three levels of soils at Avondale Research Station which had for four years received a basic treatment of superphosphate together with three different sources of nitrogen in calcium-ammonium nitrate, sulphate of ammonia, or urea at differing amounts were examined for any variation produced in the exchangeable cations, and also to see if there was any change in the nitrogen status of the soils with the sulphate of ammonia treatments.

The use of 336 lb. per acre of sulphate of ammonia had decreased the exchangeable calcium from 5 to 3 milliequivalents per 100g with an accompanying decrease in pH, the other nitrogen fertilisers having no significant effect. This same rate of sulphate of ammonia did not increase the total soil nitrogen but the mineral nitrogen increased about 25 per cent, this increase being in the ammonia form.

4. Samples of the 0-4 in. layer of ten soils typical of types in the South West which were to receive applications of muriate of potash (potassium chloride) in subsequent years, were analysed for both the total and exchangeable potassium. These soils were carrying clover and the various potassium concentrations are shown in Table 3.

TABLE 3

Property	Potassium in Soil dry basis		Potassium in Clover
	Total per cent	Exchangeable milli equivalents per 100g	Per cent
Beard, Witchcliffe	0.01	0.20	1.07
Moriarty, Witchcliffe	0.02	0.25	1.23
Woods, Rosa Brook	0.01	0.20	1.20
Dennis, Rosa Brook	0.01	0.20	0.87
Sherry, Rosa Brook	0.02	0.25	1.01
Prowse, Capel	0.01	0.15	0.78
Prowse, Capel	0.04	0.30	0.72
Merrit, Elgin	0.04	0.20	0.75
Roche, Pinjarra	0.01	0.10	0.82
Jackson, Roelands	0.02	0.15	0.64

It can be seen that the potassium contained in the clover bears no direct relationship to that in the soil.

5. Numerous other soil samples were received from private sources in connection with the failure of plants to thrive in some situations or from land being considered for development. Others again were to be used in various field and pot experiments by the Department of Agriculture.

Fertilisers

1. Fertilisers Act. There were 77 samples of fertilisers examined under the Act, compared with only 13 in the previous year and the emphasis was on fertilisers containing trace elements.

That this emphasis was justified was proved by the findings that 19 of 60 fertilisers registered for copper and 16 of 39 registered for zinc were deficient in these elements. There have been difficulties with the supply of copper minerals or salts for use as fertiliser but the same can not be said for zinc where the proportion of deficiency was even worse.

None of the fertilisers was deficient in phosphate but one of the three registered for nitrogen also did not reach the requirement.

2. The fluoride content of rock phosphate, which is important in its use as a stock food supplement (for which the fluoride should be as low as possible), was determined on samples from various sources. Christmas Island rock is the one favoured and this was found to contain 2.4 per cent fluorine, compared with Nauruan at 3.8 per cent However the work of Dr. Snook advising the use of Christmas Island rock phosphate was based on this containing less than 1.5 per cent fluorine.

A number of samples from sources now being used in Western Australia showed a wide range of fluoride, from as little as 2.2 per cent from one sample from Christmas Island up to 5.7 per cent from Senegal. Of ten samples from Juan de Nova none exceeded 1.5 per cent fluoride.

3. The amount of some trace elements present in phosphatic fertilisers without deliberate addition was examined to find how much of these would, be present in supposed nil treatments. Supers were found to contain approximately 350 p.p.m. of zinc, i.e. 0.035 per cent compared with 1.15 per cent required in a zinc-super. This could perhaps prove to be significant but copper at 18-65 p.p.m. and molybdenum 1 p.p.m. and less, would not.

The rock phosphates mentioned in connection with fluoride, which were from Senegal, Togoland, Nauru, Christmas Island and Ocean Island, were also analysed for trace elements, zinc proving again to be the one of possible importance, being as much as 0.1 per cent in the Ocean Island rock.

4. Flue dust from the electrostatic precipitators of a cement works proved to be very rich in potassium, containing approximately 28 per cent as potash K_2O, or 23 per cent as the element K. With the annual amount of dust being quite appreciable this would be a valuable, if limited, supply of this nutrient. The difficulty however lies in the very fine nature of the material, bulk density 12-19 lb. per ft^3, which makes its handling difficult and its transport expensive.

Similarly the wood ash at the Kalgoorlie Power Station was examined for water soluble potash, one of six samples containing 12.7 per cent while the others had only 1 or 2 per cent. This suggested some concentration by leaching and confirmed that wood ash is generally usable at the site but not economical to cart.

5. Interest was shown in what constituents were left in superphosphate granules which had been applied to the surface of pot experiments in a glasshouse. It was found that the residue from these granules, as with the residue from pelleted potato manure used in the field and reported in 1964, was a mixture of the insoluble form of calcium sulphate, anhydrite $CaSO_4$ and the more soluble gypsum, $CaSO_4.2H_2O$, together with a little of the less soluble forms of calcium phosphate, the water soluble phosphate having been leached out.

6. Among various other samples were guano deposits from Broome which again proved variable in composition, containing as little as 0.15 per cent to a valuable 27 per cent phosphoric acid; farm stocks of superphosphate to be checked for compliance with their labels, and fifteen samples of limesands to be examined for their neutralising value.

Pastures, Fodders and Stock Foods.

1. Feeding Stuffs Act. During the year there were six samples analysed of which four were deficient in protein and one in phosphoric anhydride. Excesses were found in three cases for phosphoric anhydride and calcium, and one each for crude fat and sodium chloride.

In one instance a feeding stuff contained, as claimed on the label, 50 p.p.m. of selenium. This had not been included in the application for registration and was considered serious because of the known difficulty of administering selenium therapeutically, and the closeness of the nutritional level to the toxic level for this element.

2. Clovers and clover pastures.

(a) Rates of Stocking. The effects of stocking rate on the nutritional status of the pasture components is being tested in a number of areas by the Department of Agriculture.

Samples of pasture from Mt. Barker showed that for the clover component, stocking at rates of 4, 5 and 6 sheep per acre, improved the content of protein, phosphorus and sulphur, whether the super rates were 1, 2 or 3 cwt. per acre. The fibre content was reduced in the same way.

There was insufficient grass in this pasture to draw conclusions as to its nutritional status.

At Avondale, stocking rates were 2, 3⅔ and 3⅓ sheep per acre, with super at 60, 120 and 180 lb per acre. Here the stocking again increased the protein and decreased the fibre. Super treatment, with stocking rate, improved the phosphorus and sulphur contents.

(b) Fertiliser Experiments.

(i) From trials at Waterloo, Manjimup and Boyanup came samples to test the maintenance of superphosphate on acid soils. These included aspects of the sulphur need, lime requirement and the value of ground rock phosphate.

At Waterloo, on Boyanup Clay, the use of limestone at 4 tons per acre improved the availability of phosphorus but not of sulphur. On the Abba Sand at Boyanup limestone was ineffective but 5 cwt. per acre of rock phosphate did increase the phosphorus concentration, and on the Karri Loam at Manjimup no combination of super and/or lime and/or calcium monophosphate and/or gypsum affected the phosphorus or total sulphur content of either the clover or the grasses.

(ii) At Muresk Agricultural College gypsum, super, aerophos, sodium sulphate and sulphur were tried at various rates on sub-clover pastures. The pasture components from this trial were analysed for phosphorus, total and sulphate sulphur and total and protein nitrogen.

For the clover no appreciable increases of sulphur or sulphate were achieved, but phosphorus uptake was increased at all rates of superphosphate from 45 to 180 lb per acre and all rates of aerophos from 19-76 lb per acre. Phosphorus treatment improved the nitrogen content by increasing the protein.

With the grass and other components again there was no increase in sulphur or sulphate, but phosphorus, by either super or aerophos additions gave a slight improvement in total nitrogen, in this case in the non-protein forms.

(iii) The clover and grass from experiments at Manjimup were analysed for phosphorus. Here the source of phosphorus and frequency of application were being tested. These samples, cut in 1963, had received phosphate treatment at two levels of total phosphorus irrespective of source and frequency, over a period of 8 years.

Early results showed rock phosphate as a poor source of phosphorus, the grass component of the pasture being severely checked. More recently the use of lime-super and heavy dressing with limestone had some benefit in increasing the grass content and the total spring yield. Frequent small applications of 2 cwt. annually gave better results than 16 cwt. as one dressing but at 4 cwt. annually or 8 cwt. biennially and 32 cwt. as one dressing there had been little difference in pasture growth in 1963.

For the clovers the biennial rock phosphate application produced a phosphorus concentration equal to that of all other forms of phosphate at the same level, but the grass which was present was comparatively low in phosphorus.

All treatments equal to 16 cwt. of super averaged 0.20 per cent phosphorus (range 0.18-0.21) for the clover, all treatments giving better results were 0.23 per cent or higher. For the grasses in the same plots the comparable figures were 0.21 (0.18-0.26) and 0.23 per cent or higher.

(iv) From an experiment to test the effect of the time of application of superphosphate and potash, samples of Mt. Barker sub-clover were examined for phosphorus, potassium, total sulphur and inorganic sulphate.

There was no benefit from super or potash applied alone, only when applied together, the maximum being obtained by dual application in both April and August. An August dressing alone gave treble the yield increase of an autumn dressing. It is not yet certain what the factors controlling this are but it has been thought that heavy winter rains and water-logging remove potash and sulphate from sandy soil.

From these ten treatments it appeared that phosphorus percentage uptake was better if applied alone, although the split autumn-spring application with potash reached the highest level. With potassium, the single application in spring, either alone or with super, achieved the maximum concentration at about three times the amount in the untreated clover. August application also gave the highest concentrations of inorganic sulphate.

(v) The benefit of potash fertiliser and the increase to be gained by split application was again shown by clover grown on Karri loam at Manjimup. The yield had increased by 90 per cent by the use of potash, and if split into autumn and spring dressings the yield was a 15-20 per cent improvement over a single application. The potassium content of the samples is shown in Table 4, with the corresponding treatments.

Table 4

Treatment KCl, lb./acre		Potassium, K per cent dry basis
April	August	
Nil	Nil	0.72
112	-	1.05
-	112	1.39
56	56	1.15
224	-	1.56
-	224	1.31
112	112	1.78

(c) Trace Elements.

(i) The residual benefit of previously applied copper fertiliser at Esperance Downs Research Station was shown to be appreciable for the 1964 winter cut of clover which without copper dressing contained 6.1 p.p.m. but which contained 9.2 p.p.m. copper resulting from 12.5 lb per acre of copper ore applied in 1950—fourteen years previously, spring cut samples being similar. For the grasses in the pasture the effect was to raise the level from 4.5 to 7.2 p.p.m. in the spring cut but no benefit was apparent in the winter cut.

On a different area where the no copper treatment nevertheless contained 11 p.p.m., addition of copper sulphate at 5 and 10 lb per acre in 1953 and 1959 raised the content of copper to 13 and 30 p.p.m. for the winter cut of clover, but only from 8 to 10 p.p.m. for the grass component. Similar treatments on a third area gave an increase from 6 to 8 and 10 p.p.m. for the clover and from 5 to 7 p.p.m. for the grass.

That the effects could be very long lasting was even better illustrated by a treatment of 4 lb per acre copper sulphate applied to clover in 1952, which in 1964 gave 6 p.p.m. copper, the required level for copper in pasture, when the untreated clover was sub normal at 3.5 p.p.m.

(ii) The effects of copper, zinc and molybdenum at three sites in the Boddington district were examined. At site A, where 10 lb per acre copper sulphate was used this produced no increase in copper concentration but had the effect of depressing zinc and potassium levels and of raising the molybdenum. At site B only zinc increased markedly with treatment at the rate of 3 lb per acre as oxide. At site C the same rate of zinc oxide again showed a doubling in zinc content of the clover; the addition of 112 lb per acre of potassium chloride raised the potassium content from 1.7 to 2.4 per cent ; the further addition of copper sulphate at 10 lb per acre raised the copper from 2.5 p.p.m. to 5-6 p.p.m., but molybdenum oxide at 2 oz. per acre did not affect the already reasonably high molybdenum content.

(iii) The cobalt, copper, molybdenum and inorganic sulphate content of pastures at Capel and Harvey were determined. If the desirable level of cobalt is accepted as 0.07 to 0.10 p.p.m. dry basis, all the Harvey clovers which had received copper and/or zinc fertiliser were deficient but not those which had super or aerophos and gypsum annually. The clovers which had not received copper ranged from 3.9 to 4.9 p.p.m., which was raised to 6.3 p.p.m. by one treatment with copper in 1960.

Grasses in these same pastures had slightly less cobalt than the clover, the copper was about the same, and the molybdenum was greater. The sulphate content of the grasses was also greater than that of the clovers.

The Capel clovers contained rather greater amounts of cobalt without treatment, 0.05-0.08 p.p.m., which levels were raised to 0.37 p.p.m. by the use of 8 oz. per acre of cobalt sulphate. Molybdenum was in excess of 2 p.p.m. for all of these, with coppers ranging 6.5 to 8.1 p.p.m. and inorganic sulphate 0.10 to 0.23 p.p.m.

At Capel the untreated grasses were only 0.02 p.p.m. cobalt and treatment raised this to 0.1 p.p.m. The copper was only about one half of that in the clover and did not improve with treatment, and the molybdenum and sulphate were of the same order as for the clover.

(iv) There were a number of selenium analyses on clovers, clover from Cunderdin containing 0.07 and 0.11 p.p.m. dry basis.

Two clovers from Boyup Brook, on which sheep had died from Water Belly in 7 days but had few urinary calculi and yet had ruptured bladders, were found to have 0.09 p.p.m. in the Geraldton and 0.02 p.p.m. in the Dinninup strains. Kidneys from four of these sheep contained 3.1 to 4.2 p.p.m. selenium, dry basis.

3. Miscellaneous Pastures and Feeding Stuffs.

(a) 120 grass pastures from Merredin were analysed for total and protein nitrogen. These had received rates of urea from nil to 500 lb per acre applied at different times and had been cut four weeks apart in September and October when mature.

The dry weights obtained at the September cut were improved by all rates of urea up to 250 lb per acre and also by later application. For the October cut again 250 lb per acre was sufficient to give maximum yield but the earlier application gave better yields up to 150 lb. per acre.

For the earlier application time the protein and total nitrogen concentrations did not reflect the improved yield until the 200, 250 lb rates, but with the later application there was a continual increase in both levels and for both cuts.

(b) Sudan grass and sorghum grain at Camballin were compared for their value as feeding stuffs. The former proved greatly superior in protein content at 10 per cent compared with sorghum 5.5 per cent dry basis; the difference here being reflected in the sudan having lower carbohydrate content.

The protein content of 49 samples of samphire (Arthrocnemum) from many places where it is being used in the reclamation of saline soils was found to vary from 6.2 to 16.8 per cent. This may not be usable as pasture however since the plants also contained as much as 30.2 per cent of common salt.

(c) Selenium determinations included the following. Some, being for diagnostic purposes where white muscle disease or illthrift was suspect, contained values ranging from 0.01 to 0.4 p.p.m. Others were from plants known to be capable of accumulating selenium and at Moore River these contained 0.20 p.p.m., but two pastures from Bridgetown had 17 and 26 p.p.m.

(d) The great variety of other materials falling under this heading included various feeding stuffs, manufactured or processed, ranging from chick crumbles, whale solubles and meal to apple pulp, the residue from which the juice has been extracted, and wild radish and turnip seed for the toxic principles, iso-thiocyanates.

Cereals.

1. Oats.

(a) Leaves, straw and grain, 75 samples, taken at Esperance Downs Research Station, were from an area commenced in 1959 as a rate of superphosphate on clover trial. In 1964 this was cropped to Avon oats.

Below is Table 5 showing the variations in nitrogen, phosphorus and sulphur content of the plant parts, the figures being the average of 5 plots.

Table 5.

Treatment lb./acre superphosphate	Nitrogen, N			Phosphorus, P			Sulphur, S		
	per cent dry basis								
	l	s	g	l	s	g	l	s	g
56	3·35	0·89	1·29	0·30	0·10	0·18	0·24	0·09	0·12
112	3·32	0·89	1·32	0·38	0·13	0·22	0·24	0·09	0·11
168	3·24	0·88	1·31	0·41	0·13	0·23	0·24	0·09	0·12
224	3·15	0·90	1·31	0·48	0·16	0·26	0·24	0·09	0·12
448	3·07	0·88	1·24	0·74	0·22	0·32	0·24	0·08	0·11

l = leaves (August, 1964), s = straw (October, 1964) and g = grain.

There is a strong tendency for increased superphosphate to suppress the concentration of nitrogen in the leaves, but this was only reflected in the grain by the heaviest application. Sulphur was not affected by any treatment but the increase of phosphorus with treatment shown in the leaves appeared consistently in the harvested grain.

(b) Further Esperance work studied the effects of urea as reflected in the oat grain. The rate of application had been found to increase the yield and time of seeding had influenced both the yield and the bushel weight, but the nitrogen content was not affected by the seeding time, and no consistent effect was obtained by either rate or time of application of the urea.

(c) There were variations in nitrogen content of the oat plants of another Esperance experiment with urea. Avon oats had received no nitrogen, 50 and 100 lb per acre at seeding and 3 weeks after, and had been seeded at three 3-weekly intervals.

The latest planting resulted in the highest nitrogen content and this was higher for those plants which received the urea at seeding, although the earlier seeded plants tended to benefit more by receiving the urea subsequent to seeding.

(d) The first crop of oats grown on the Wiluna Research Station was submitted to determine how oats performed with treatment by urea or potash. The protein content has been improved appreciably by the use of urea fertiliser as is shown in Table 6.

Table 6.

Treatment	Control	+ Urea	+ Potash
	per cent dry basis		
Ash	7·6	9·6	7·5
Crude protein (N x 6·25)	6·7	10·0	6·6
Crude fat	2·2	2·4	2·2
Crude fibre	27·7	27·8	28·0
Nitrogen free extractive	56·8	50·1	55·7
Phosphorus, P	0·16	0·19	0·16

(e) Rolled oats were examined for their value as a food, that is for their protein and energy value, or calorific value, as a preliminary to the promotion of sales by the Grain Pool in Japan and China. The protein content ranged from 9,2 to 12.8 per cent and the calorific value from 406 to 422 kilo-calories per 100 gram, a kilo-calorie being the unit termed "calorie" by the nutritionist.

2. Wheat.

(a) The nitrogen content in various forms and the molybdenum levels in wheat tops collected from experiments at Bodallin were determined. This followed the finding in the previous year that where molybdenum increased growth, the nitrate accumulation in untreated plants was significant, this indicating molybdenum deficiency in the wheat plants. Contrary to the usual finding that molybdenum supplied to deficient plants increased protein concentration, this work had shown a fall in concentation although the overall yield of protein per acre was increased.

With this year's experiments vegetative growth had again been increased by molybdenum. The treatments involved the use of both copper and zinc fertilisers in addition to molybdenum supplied as roasted molybdenite.

The findings this time were that while in one experiment there was again an accumulation of nitrate in the untreated compared with treated plants, this was not so with the second. The difference was not explicable in terms of molybdenum concentration since this was the same for both series of untreated plants. Once again however the protein concentration was decreased by molybdenum treatment.

Wheat grain from this same series of experiments, was used to compare the effects of urea fertiliser with and without addition of molybdenum. It was found that urea treatment increased protein concentration. Molybdenum addition had the effect of decreasing the protein and total nitrogen concentrations. Treatments are in lb per acre of urea and molybdenum is 2 oz. per acre of molybdenum trioxide, Table 7.

Table 7.

Treatment	Nitrogen per cent dry basis			
	Protein		Total	
Molybdenum trioxide oz./acre	*Nil*	2	*Nil*	2
Urea lb./acre —				
0	1·69	1·60	2·04	1·92
24	1·72	1·67	2·05	1·99
50	1·80	1·76	2·22	2·14
76	1·92	1·80	2·25	2·12

(b) Total nitrogen was determined on wheat tops from an experiment at Wongan Hills where anhydrous ammonia and urea were being compared as sources of nitrogen. The ammonia was applied at various times relative to seeding and at rates equal to 24, 42 and 55 lb per acre of nitrogen and at depths of 4, 6 and 8 in. Urea was added at equivalent rates.

When applied before seeding it was necessary to use the ammonia at the maximum rate to achieve a noticeable increase in nitrogen and then only at 6 in. depth. Applied at seeding the 8 in. depth gave the highest figures for the three rates as a whole, but both the 4 and 6 in. effectively raised the concentration at the highest rate.

Only when urea was applied four weeks before seeding and at the maximum rate was an increase obtained at all from this source.

From the work under (a) it appears that the grain would be a better sample to assess the merits of these treatments.

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(c) Samples of flag leaves of wheat from a number of varieties some of which had been sprayed with 50 lb per acre of urea were tested for their urease activity.

It was found that for samples which had received urea treatment in the field, the apparent activity at the time of analysis was greater if no further urea was added. This was explicable as being due to the urease activity being stimulated by an initial contact with the substrate, but suppressed by a later treatment.

(d) The 1964-65 F.A.Q. wheat and flour milled from it in a Buhler laboratory mill were analysed as below:

	F.A.Q. 1964-65 Wheat	Flour
	per cent	
Moisture (1 hour at 130°C)	9.9	12.7
Ash (at 13.5% moisture)	1.22	0.41
Protein (Nx5.7) (at 13.5% moisture)	9.0	8.0
Maltose (Kent Jones)	—	3.05

Plant Nutrition

1. Apples.

(a) 64 samples of apple leaves from Donnybrook where young apple trees had received all combinations of several levels of nitrogen, potassium and phosphorus fertilisers with four replications, showed little or no effect on the content of these nutrients in the leaves. These were for nitrogen an average of 2.46 per cent (range 2.23-2.99), for phosphorus 0.11 per cent (0.07-0.15) and potassium 1.81 per cent (1.16-2.23). By the assessment of Emmert, N.Z. J. Agr. Res. 1962, 5, 381 these trees have adequate nitrogen and potassium but are deficient in phosphorus.

Trees at Manjimup receiving a similar fertiliser treatment again showed no gains in potassium or phosphorus content, but an increase in nitrogen was achieved.

(b) Leaves from trees at Bridgetown taken from unhealthy and from vigorous and better fruit bearing trees were compared for a number of nutrients. Of these calcium was the one which at an average of 0.94 per cent for the unhealthy trees, compared unfavourably with the 1.19 per cent found in the better specimens.

Similarly poor and good trees at Manjimup, both of which had been under sawdust mulch and received 2 lb of nitrogen per tree were compared. In this instance the status of all nutrients was higher in the better tree leaves.

(c) 27 samples of leaves from trees at Stoneville Research Station said to be showing symptoms of calcium and phosphorus deficiencies had the following nutrient contents, calcium 1.14 per cent (0.91-1.48), nitrogen 2.26 per cent (2.09-2.42), phosphorus 0.17 per cent (0.15-0.19), potassium 1.54 per cent (1.46-1.68). The trace elements in these trees were copper 6.2 p.p.m. (5.2-7.9), manganese 56 p.p.m. (40-75) and zinc 16 p.p.m. (14-22).

Emmert's assessment would make these to be at the critical level for calcium and deficient in phosphorus.

These results can be compared with trees at Parkerville said to be deficient in phosphorus and copper which were certainly low in phosphorus at 0.13-0.16 per cent but contained 10-14 p.p.m. of copper.

2. Pears.

(a) Pear fruit from the tops and bottoms of trees at Parkerville were examined for boron to see what part if any this element played in the decline of some of the trees. Healthy trees on one property had boron levels at top and bottom of 25 and 27 p.p.m., and for the unhealthy trees of 20 and 21 p.p.m. This may however have only been symptomatic of decreased vigor since healthy trees on a nearby property gave results of 22 and 20 p.p.m.

(b) Pear leaves from a property at Roleystone suspected of manganese deficiency had manganese contents of 84 and 64 p.p.m. dry basis.

3. Citrus.

(a) Unlike the apple leaves above, seventy-two samples of orange leaves from Capel which were from an experiment in which several levels of nitrogen, phosphorus and potassium fertilisers were used in combination, with four replications, did reveal some responses in leaf concentration with treatment.

Nitrogen uptake increased with nitrogen treatment and was unaffected by phosphorus and/or potassium treatments. Potassium uptake was suppressed by nitrogen treatment, but the levels were satisfactory to high without potash addition and with treatment reached levels which, at 2 per cent, could be considered excessive.

(b) Some Carnarvon soils are unusually high in exchangeable potassium which can lead, on overseas experience, to yield reductions and leaf scorch of beans, citrus and avocados. For this reason three citrus varieties were examined with the following results.

Table 8.

Variety .... / Vigor	Navel / Good	Valencia / Good	Grape-fruit / Poor-good	Satis-factory level
	per cent dry basis			
Calcium, Ca	4·61	6·22	4·36	3–6
Magnesium, Mg	0·40	0·51	0·49	0·3–0·7
Potassium, K	1·77	1·20	1·27	0·7–1·5
Sodium, Na	0·25	0·26	0·29	less than 0·17

The indication here is that if leaf scorch does occur it is more likely due to high sodium content than to potassium.

(c) Citrus trees at Gosnells were suffering from excessive leaf drop, believed to be due to high foliar salt. Leaves and bark from six trees were analysed for sodium and chloride. Affected leaves were found to contain from 0.41 to 0.50 per cent sodium and unaffected leaves had 0.27 to 0.37 per cent, so that even the leaves said to be normal are very high in sodium.

(d) Samples of healthy mandarin leaves from Upper Swan were compared with curled leaves from Mooliabeenie, thought to be deficient in either, or all, of boron, copper and molybdenum. The boron contents were satisfactory to high; in both cases the molybdenum at 0.02 p.p.m. was low, but the marked contrast lay in the copper content. The healthy leaves contained 105 p.p.m. while the unhealthy had only 3.1 p.p.m.

4. Avocado. Associated with the citrus leaves above were two samples of avocado leaves from Carnarvon. With these the potassium content, 1.98 and 1.70 per cent was higher and the sodium content so low, at 0.03 and 0.06 per cent, as to suggest that leaf scorch, in this case said to occur in March-April, is not related to their potassium or sodium content.

5. Currants.

(a) The moisture content of dried currant fruits was determined to calibrate a Moisture Meter used in the Swan Settlers packing shed. It was found that while the meter was only reading about 1 per cent out on the average at the 15 per cent level, some readings at this level could be as much as 2.5 per cent too high.

(b) Moisture was also determined on dried currants from Lower Chittering and Caversham where differing methods of fruit setting using cincturing, P.C.P.A. or giberellic acid at different times, appeared to give different rates of drying. The moisture contents were found to be very consistent for each area, with the exception of the Lower Chittering samples where giberellic acid had been used. For these the moisture was 1.2 per cent higher than for the other methods.

6. Cotton and Rice. Two cotton leaf samples from plants at Kununurra with and without copper treatment were found to have precisely the same boron, copper and zinc contents at normal to high levels, but the nil treatment contained only 16 p.p.m. manganese as against 290 p.p.m. in the treated sample.

Rice leaves from the same area had copper levels 14 to 17 p.p.m. with or without treatment, but the boron 6 to 8 p.p.m. and zinc 9 to 11 p.p.m. would be considered low for pastures and cereals. There were striking differences in manganese between one of the nil treatment samples at 27 p.p.m. and the other three samples which contained 290 to 440 p.p.m.

Animal Nutrition.

1. Cobalt and Copper.

(a) The livers of sheep on a property at Donnybrook with problems of ill thrift, contained 0.15 to 0.20 p.p.m. dry basis cobalt and 370 to 630 p.p.m. of copper.

(b) As part of a cobalt survey of the Esperance district sheep livers were found to contain 0.21 to 0.29 p.p.m.

(c) Stock losses in the Ashburton were believed to be associated with heavy metal poisoning but cobalt 0.28, copper 280 and lead 0.7 p.p.m. in the liver did not support this suspicion.

2. Copper and Molybdenum.

(a) Foetal calf livers from animals which had aborted on a property at Waterloo which had been top dressed with a high rate of molybdenum, were found to contain 190 p.p.m. copper and 0.36 p.p.m. molybdenum.

(b) A bovine liver from Brookhampton was found to contain 16 p.p.m. copper and 0.18 p.p.m. molybdenum. This was in an area where there had been a very serious outbreak of mortalities.

3. Miscellaneous. There was a range of other determinations on various viscera for diagnostic purposes; nitrate, and nutritional elements calcium, magnesium and phosphorus on stomach contents, kidneys for selenium.

Miscellaneous.

1. Blood Alcohol. 69 samples of post mortem blood, an increase of 14 for the year, were analysed for alcohol by the Kozelka and Hine method for comparison with results obtained in the Food and Drug Division.

2. Oil Seeds. There was also an increase in the number of oil seed determinations from 293 to 435, represented by 82 samples of safflower and 353 samples of linseed, these being analysed for oil content and some for iodine value.

3. Spectrographic. Minerals on which semi-quantative spectrographic analysis was carried out included, 3 zinc and lead ores for cadmium, 22 dolomites and 12 granites from the Ashburton area for all elements detected, and a tantalite from Ravensthorpe.

Fertilisers were a limesand for nutritive elements and a copper ore for toxic elements.

Wheat plants from Bodallin, where differences in germination between the applications of copper ore and copper sulphate were obtained, were not significantly different in concentration between samples and no element was present at toxic levels.

Samples of laterite occurring over hills of Carson volcanics in the Kimberley Group of the North Kimberley area, were analysed by Atomic Absorbtion Spectrophotometry for copper, lead, zinc, nickel, antimony and bismuth, which were of interest to the Geological Survey for geo-chemical reasons.

4. Fire Extinguishers. At the request of the Western Australian Fire Brigades Board a number of fire extinguishers of the Water (Soda Acid) type, and Foam (Chemical) type, and the charges used in them were examined. The examinations were made with the Australian Standard Specifications, and the maintenance standards of Australia, Britain and the United States of America in mind, in the light of the following requirements:

(a) In order to decrease the expenses of the operations of the Board it was desired to reduce both the time taken in maintenance of extinguishers and the amount of chemicals consumed.

(b) Chemical tests were believed by the Board representatives to provide an alternative to the present system of discharging and recharging the extinguishers annually.

(c) It was desired to conform with Australian Standard Specifications with regard to size and contents, etc. but to find satisfactory alternatives to the maintenance requirements.

Following the examinations and tests it was concluded that:

(i) It is clear from all Standards examined that the object behind the required recharge or discharge interval is primarily a check that corrosion or mechanical deterioration has not affected the efficiency of the extinguisher and not a check on deterioration of the chemicals.

(ii) In respect of size, charge, acid bottle and rate of discharge some extinguishers at present in use do not comply with Australian Standards.

It has been shown that the absence of a standard requirement for stabilizer makes an annual discharge advisable for Foam (Chemical) Extinguishers.

(iv) Dilution of the acid charge does not affect performance of Water (Soda Acid) Extinguishers.

(v) Since there is a very wide margin for variations in both soda solution and acid, an annual discharge of Water (Soda Acid) Extinguishers is excessive, and an examination for corrosion, etc. with biennial discharge as with the British Standard would be adequate.

(vi) Chemical testing of the soda solution of the water type is quite feasible but compliance with the standard would only be shown by having the capacity recorded correctly.

(vii) The presence of a stabilizer of unknown composition renders chemical testing of soda solution for foam types impractical.

(viii) Chemical testing of the acid is not necessary or practical during maintenance.

(ix) Chemical testing of acid salt solution is impractical because of lack of restrictions on composition, but compliance with the provision for foam production is essential.

(x) The required concentration of soda solution of water type extinguishers is 5 per cent and not 7 to 8 per cent as used at present. Possible tests for determining these concentrations were included.

Based on these conclusions recommendations were made to the Fire Brigades Board.

Water and Water Treatment.

Of the 1,701 samples of water and 16 deposits received a few of particular interest have been selected for discussion. The sources of water, and the problems involved with its use, stretch over the entire State.

1. Corrosion, Scales and Deposits.

(a) At Princess Margaret Hospital the evaporative condenser, used in air conditioning, was extensively corroded in a very short time. The original coating of the steel structure, which had been defective, had been replaced by a zinc-silicate treatment finished with bitumen based paint.

A filming amine is now to be used to inhibit future corrosion. If this should prove inaffective alternatives which should be tried at the first sign of breakdown were recommended.

(b) Examination of a deposit from the condenser of the air conditioning unit at Port Hedland Hospital and of the condenser water seemed anomalous. The scale contained practically no calcium carbonate, being mainly magnesium hydroxide and silica together with organic matter from the D.M. treatment. It seemed that the deposit may have been the less acid soluble residue left after descaling with inhibited acid.

Analysis of the water indicated a fourteen fold concentration of the town supply. It was recommended that, using softened make up water:

(i) The water should not be allowed to concentrate more than five fold.

(ii) The pH of the condenser water should be controlled at about 7.5, by using acid addition.

(iii) If the condenser system is all copper the present treatment be discontinued and replaced by polyphosphate at 15 to 30 p.p.m. in the condenser water.

(c) The Albany Regional Hospital had trouble with corrosion of the cusilman bronze hot water calorifiers and the copper steam heating tubes. The corrosion of the former was pitting near, and of, welds and in high temperature regions. This was considered to be due to release of oxygen in these areas due to roughness or to their being more cathodic due to heat effects.

Corrosion of the tubes was pitting on the water side and was probably due to oxygen attack at temperatures in excess of 160°F., in the presence of free carbon dioxide and high chloride.

To alleviate the corrosion it was recommended:

(i) The calorifiers should be vented or fitted with air eliminators at the highest point.

(ii) If (i) did not prove completely effective it might be necessary to replace the thermo-syphon with recirculating pumps so that the temperature in the calorifiers can be reduced.

(iii) Alternatively dosing the cold feed water with soda-ash to raise the pH to about 8.4 would considerably reduce the corrosion.

(d) The air conditioning plant at a city store was another with a corrosion problem. Copper pipes in the cooling tower were pitted through as the result of the evaporation of droplets of water containing a high concentration of salt. This high concentration indicated that bleed off had been reduced or blocked.

It was suggested that the salt concentration of the condenser water be kept below 3,000 p.p.m. and if possible the sprays be arranged so as to keep the copper piping constantly wetted.

(e) Corrosion of the steam header of a boiler at N-gala home was found to be caused by insufficient control of the treatment of the boiler water. The concentration of the additives was far from the amounts recommended by the suppliers and the slug dosing was being added at the wrong point in the system.

Continuous dosing of the feed tank, daily control tests of the boiler water and the use of filming amine to protect the condensate lines and prevent copper pick-up were recommended.

(f) A problem exists at Council House that ground water was causing flooding of the basement and scaling in the pumps and pipes used to remove the water. Beneath the building is a layer of no-fines concrete laid to drain any seepage to the sumps. The seepage had become excessive due to malfunction of the external agricultural drains, and the no-fines concrete had begun to block because of the deposit.

It was found that the groundwater, because of its free carbon dioxide content, is capable of dissolving lime from the concrete in its passage to and through the no-fines. On exposure to air in the no-fines or pumps it loses carbon dioxide, thereby increasing in pH and causing the deposition of calcium carbonate.

At the time of sampling, the pore space in the no-fines concrete appeared to be approximately one-third filled, but this does not mean that it will fill entirely in a few years time since the rate of deposition will decrease as the concrete matures.

However, the large volume of water entering could be best reduced by lowering the water table against the building by more efficient external drainage.

2. Metropolitan Water Supply. Routine sampling of hills reservoirs and bores in the metropolitan area continued throughout the year. In addition new bores being drilled by the Geological Survey in an exploratory programme for additional supplementary supplies, were tested for quality as were samples from streams in the hills which might form the supply to future hills catchments.

Treatment of the water to ensure bacteriological purity and at the same time minimise future consumer complaints of dirty water, resulted in a larger number of reported tastes in different areas.

(a) As an example of problems which can arise, algal growth in the Mt. Yokine Reservoir, together with the free residual chlorine which remains from chlorination at the hills reservoirs, was associated with consumer complaints of taste in the water.

The algae species was identified at the Botany Department, University of Western Australia, as Pamellococcus which was not reputed to cause tastes while living, but the death of the algae resulting from the chlorination was probably the cause. In order to minimise future tastes, and at the same time have the available chlorine in a form which would be longer lasting, it was recommended that four parts of ammonium sulphate be added at the inlet for each three parts of free chlorine in the incoming water. The formation of chloramines should reduce the likelihood of tastes being produced either from algae or from pipe-wall growths.

It was further recommended that at the first sign of algae in the reservoir copper sulphate should be added at the rate of 1 p.p.m. or up to 4 p.p.m. if the algae is resistant.

(b) Depth Sampling—Serpentine. In order to gauge the variation in quality of the water held in Serpentine Dam, depth sampling has been carried out since its inception. Results for 1965 showed an improvement in the hyperlimnion water compared with samples at about the same time in 1962, 1963, 1964. There should be a continual improvement in the quality of this water in future years as the organic matter in the bottom of the dam is stabilised, giving conditions similar to those existing at present in Canning Dam.

(c) To see what part chlorination of the water at Serpentine would contribute to tastes and odours, tests were made first with ammonia free distilled water and then with water from two levels of the reservoir.

It was first established that the taste of chlorine in ammonia free distilled water even at levels of 5 p.p.m. could be detected by only 50 per cent of the tasters. 1 p.p.m. is capable of producing an odour but this is rapidly dissipated on exposure to the atmosphere. 0.5 p.p.m. chlorine gave neither smell nor taste.

Secondly it was found that even 10 p.p.m. of phenol was odourless, and could be tasted by only 50 per cent of the tasters. However 0.001 p.p.m. of phenol if first treated with 1 p.p.m. chlorine could be tasted by all, the taste being distinguished from that of chlorine alone.

Further tests were then made with water containing 0.4 p.p.m. nitrogen as ammonium ion. With the addition of chlorine, chloramines are formed, and when the chlorine added was 3 p.p.m., at which point trichloramine, NCl_3, begins to be formed, 50 per cent of the tasters could detect the taste. Relevant data for the waters from Serpentine are given in Table 9.

Taste tests of these chlorinated samples showed little or no improvement by the use of breakpoint chlorination over normal chlorination. Breakpoint chlorination is reputed to correct tastes of biological and phenolic origin. The only satisfactory method of reducing or eliminating the tastes was by dechlorination after breakpoint chlorination.

Dechlorination with ammonia, strictly removal of free chlorine, reduces but does not eliminate taste whereas dechlorination with sodium thiosulphate is effective. The latter treatment however leaves the water with no antibacterial qualities.

It was therefore recommended that where "dechlorination" is practised it is by the use of ammonium sulphate added at the rate of one part for each part of free chlorine. This means that the available chlorine is in the form of chloramines which have greater stability and less potential for taste production.

Table 9.

—	Serpentine Reservoir 11/3/65	
	Surface	Hyper-limnion
pH	7·2	6·6
	parts per million	
Sodium chloride (calc. from chloride)	130	104
Phenols	0·002	0·006
Nitrogen—		
Free ammonia	0·16	0·04
Albuminoid	0·11	0·05
Chlorine dosage—		
1. Residual 0·1 p.p.m., 1 hr.	0·5	0·5
2. For breakpoint	1·5	1·0

(d) A curiosity was a sample of water from the bore at South Perth Zoo. The present analysis of this water was almost identical with that done in 1904 when the bore was first put down.

3. Country Water Supplies. A great number of samples from the Geological Survey and the Public Works Department were concerned with the provision of water supplies to country towns including many in connection with the new developments in the North of the State. The majority of samples from private sources were required for agricultural purposes on individual properties but a number were concerned with the problems resulting from domestic use and consumption by industries.

Chlorination has also been introduced to some country towns and similar problems have arisen to those experienced in the metropolitan area. The deposits which build up on the walls of the reticulation, the release of which is the primary cause of dirty water complaints, are removed as the result of chlorination, and while every care is taken to scour the treated pipes there are occasions when the voluminous flocculent brown deposits, consisting mainly of rust and silt bound together by organic matter, come through the consumers' taps.

This is the penalty which must be paid initially for the introduction of chlorination. The benefits of which the consumer is not sufficiently aware, are water which is free from bacteria and therefore safer from all aspects of health, and fewer dirty water problems once the system is stabilised. There are secondary benefits in that, for instance, the removal of growths from the pipes joining Wicherina to Geraldton resulted in a freer flow of water.

4. Various other samples were of interest.

(a) A groundwater from Bayswater had total dissolved solids of 265 grains per gallon but only 23 g.p.g. of sodium chloride. It was found to contain 23 g.p.g. of iron compared with a normal iron content measureable in parts per million. This suggested it was either polluted with industrial effluent or that it derived from a peaty soil.

(b) Confirmation of the high nitrate content of waters in the Wiluna area was obtained from a bore and a well on Mt. Springs Station. These contained 150 and 85 p.p.m. nitrate rendering them unsuitable for drinking by infants.

(c) Water from Garden Island, considered for use for industrial development, was found to be similar to the deep artesian bore waters used in Perth by the Metropolitan Water Supply Board to mix in with hills catchment water. Because of its relatively high total salts content it would be of limited industrial use.

(d) The water produced from a locally designed deionising plant was examined for compliance with the requirements of the British Pharmacopoeia for purified water. After the initial taste derived from the fresh resins has disappeared the water was of the quality required for pharmaceutical preparations.

(e) Pilot plant work on the removal of iron from bore water by oxidation with potassium permanganate and then removal by exchange and catalytic filtering on manganese zeolite, was carried out in co-operation with a local paper manufacturing company.

The pilot plant consisted of a small filter unit, approximately 5 square feet in cross section with a 4 feet bed depth of manganese zeolite. Potassium permanganate solution was fed into the bore water from a 2 ozs. per gallon solution with a small feed-pump. The raw bore water had the following analysis.

	Raw Bore Water.
pH	6.7
	parts per million
Total dissolved solids	560
Iron, Fe	2.8
Manganese, Mn	0.04
Total alkalinity (as $CaCO_3$)	180

With varying throughput of 700-2,100 gallons per hour it was found possible to reduce the iron content to less than 0.1 p.p.m. and to produce a treated water that was clear, colourless and stable. However the managanese content of the treated water could not be lowered below 0.6 p.p.m. and with feed rates as high as 100 ml per minute of 2 ozs. per gallon solution of potassium permanganate, levels up to 2.1 p.p.m. of manganese were found.

Subsequent paper making tests by the company showed that treated water with 0.6 p.p.m. manganese could not be used for high quality white paper but could be used for lower grades of paper. Examination of the economics of treating the bore water, showed that it would be cheaper to use treated water than scheme water.

ENGINEERING CHEMISTRY DIVISION

During the year the staff of the Division consisted of the Divisional Chief, two graduate professional officers, one science (chemistry) cadet, three laboratory technicians, one laboratory assistant, one drafting assistant, three and later two fitters, and one labourer.

The Division was thus understaffed in the sense that the Chemist and Research Officer, Grade 1, Mr. R. G. Becher, was the whole year absent on leave, the staff being augmented by a cadet (University undergraduate).

Most of the work during the year was done for outside interests as sponsored projects, two of them being continued from the previous year.

Three original research and development projects into the commercial utilisation of natural resources of the State were conducted during the year, two of them, viz. production of lightweight aggregate for concrete from local shale on pilot plant scale, and utilisation of titaniferous magnetite deposits containing vanadium (at Coates Siding) being continued from the previous year, and one, viz. the effect of the method of heating beach sand on its electrostatic separation was initiated during the year.

A most significant event during the year internally was the completion in October of the new mechanical workshop building, which includes also a welding bay, and store rooms for fittings, tools, pipes and other materials.

A portion of the pilot plant building, formerly occupied by the mechanical workshop, thus became available for installation of further pilot plant equipment.

As to the pilot plant equipment, a fibreglass Humphrey's Spiral for separation of minerals was installed, a new type of high tension electrostatic separator with 12 in. diameter disc was designed and built by the Division, (Fig. 1) and a "Birlec" globar high temperature electric furnace was modified and re-built by the Division's staff.

Utilisation of Titaniferous Magnetite Deposits Containing Vanadium, at Coates Siding (Lab. No. 6100/64)

This work was commenced in 1964 to find ways and means for the utilisation of the deposits, possibly at Wundowie Charcoal Iron and Steel Works, in order to diversify the production of the latter works.

The Annual Report for 1964 contains (a) description of the deposit, an estimated 8.2 million tons of weathered rock (ore) and possibly over 32 million tons of original gabbroic rock (ore), situated about two miles from the Wundowie Charcoal Iron and Steel Works and, (b) the results of preliminary exploratory work.

The analyses of bulk samples of weathered and original unaltered ore, and of a representative sample of cap rock (0-12 ft. level), as given in the 1964 Annual Report, are tabulated below. (Table 10).

Table 10.

Sample	Level	Iron, Fe	Titanium, Ti	Vanadium, V
	ft.	per cent	per cent	per cent
Cap rock	0-12	40·6	4·45	0·44
Weathered ore	17-95	32·2	4·45	0·40
Original ore	Below 95	27·5	3·55	0·29

Complete analyses by Mineral Division of original ore and of weathered ore are given in Table 11.

Table 11.

Complete Analyses of original ore and weathered ore.

—	Original ore (Lab. No. 6957/64)	Weathered ore (Lab. No. 10393/64)
	per cent	per cent
Silica, SiO_2	29·5	22·94
Alumina, Al_2O_3	12·7	19·19
Ferric oxide, Fe_2O_3	20·8	33·72
Ferrous oxide, FeO	16·6	3·96
Iron sulphide, FeS_2	0·64	n.d.
(Total iron, Fe	27·8	26·69)
Titanium dioxide, TiO_2	5·92	6·11
Vanadium trioxide, V_2O_3	0·43	0·42
Calcium oxide, CaO	5·78	n.d.
Magnesium oxide, MgO	2·71	0·08
Sodium oxide, Na_2O....	1·64	0·08
Potassium oxide, K_2O	0·28	0·32
Phosphorus pentoxide, P_2O_5	0·02	0·039
Manganous oxide, MnO	0·18	0·13
Sulphur trioxide, SO_3	....	0·37
Free moisture, H_2O-	0·39	1·67
Combined water, H_2O+	2·28	11·04

n.d. = not detected.

Concentration.

(1) Original ore. As described in the 1964 Annual Report, preliminary tests indicated that the best concentrate was obtained using wet magnetic separation of the ore crushed to minus 35 mesh and to minus 20 mesh. Further tests during 1965 confirmed this, indicating also that recoveries of valuable components in the magnetic fractions were higher with the coarser feed (minus 20 mesh) but grades were lower than with minus 48 mesh feed. In general, the best overall results were obtained with the feed of minus 35 mesh or minus 48 mesh Tyler.

The analyses of representative samples of magnetic and non-magnetic fractions are given in Table 12.

Table 12.

Analyses of Magnetic Concentrate and Non-Magnetic Tailings from original ore.

—	Magnetic Concentrate (Lab. No. 10394/65)	Non-Magnetic Tailings (Lab. No. 10395/65)
	per cent	per cent
Silica, SiO_2	3·56	40·96
Alumina, Al_2O_3	0·99	17·75
Ferric oxide, Fe_2O_3	52·79	6·69
Ferrous oxide, FeO	27·40	12·06
Metallic iron, Fe	0·11	0·05
Pyrite, FeS_2	0·056	n.d.
(Total iron, Fe	58·55	14·12)
Magnesium oxide, MgO	0·54	2·87
Calcium oxide, CaO	n.d.	8·21
Sodium oxide, Na_2O	0·11	2·32
Potassium oxide, K_2O	0·05	0·39
Titanium dioxide, TiO_2	11·49	3·73
Phosphorus pentoxide, P_2O_5	0·022	0·12
Vanadium trioxide, V_2O_3	1·12	0·12
Manganous oxide, MnO	0·25	0·18
Sulphur trioxide, SO_3	n.d.	1·07
Free moisture, H_2O-	0·12	0·50
Combined water, H_2O+	1·69	2·95

(2) Weathered Ore. In the Annual Report for 1964 it was noted that magnetic separation—dry or wet—was unsuccessful in concentrating weathered ore, which is naturally in a finely divided state.

Laboratory decantation and elutriation tests indicated that some concentration of iron, titanium and vanadium could be achieved by gravity separation. The use of Wilfley table yielded a heavy fraction containing 80 per cent of vanadium in 57 per cent of original weight, and 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:

- Iron, Fe—48.0 per cent equivalent to 68.0 per cent of Fe_2O_3.
- Titanium, Ti—6.7 per cent equivalent to 11.0 per cent of TiO_2.
- Vanadium, V—0.6 per cent equivalent to 1.07 per cent of V_2O_5.

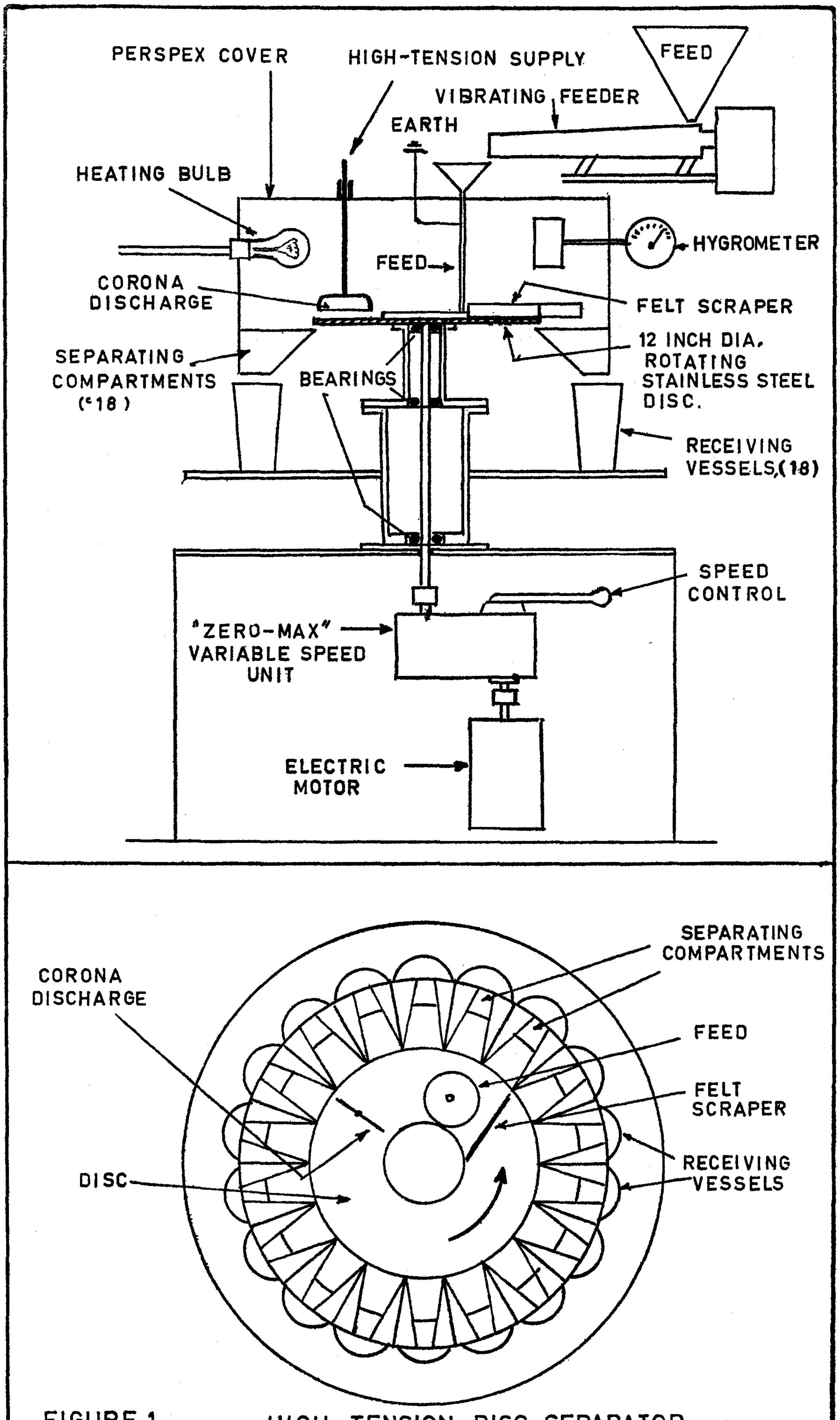


FIGURE.1. HIGH-TENSION DISC SEPARATOR

Possible concentration of weathered ore by froth flotation was investigated by the Kalgoorlie Metallurgical Laboratories. The summary of their report No. 735 of November 5, 1965—"Concentration of Low-Grade Vanadiferous Iron Ore from Coates, near Wundowie, W.A."—is.

"No flotation techniques or reagent combination was devised that produced a high-grade iron concentrate."

Generally, the concentrate produced assayed 40 to 45 per cent Fe, recovering 60 to 70 per cent of the iron. Slight improvement in concentrate grade usually resulted when the ground ore was deslimed before flotation. The best concentrate grades were produced in tests where the ore was finely ground (minus 300 mesh) and deslimed before flotation.

The results of magnetic separation on the plus 300 mesh portion and gravity concentrates produced from the ground ore (all minus 72 mesh) indicated that although portion of the iron materials was relatively free, a large proportion of the iron was intimately associated with the gangue materials.

It is most unlikely that a flotation process could be devised that would recover a high percentage of iron in a concentrate assaying 60 per cent Fe^{++}.

Following earlier tests, reported in the 1964 Annual Report, further magnetising roasts of weathered ore were made, following by magnetic concentration.

The magnetising roasts were made in a 6 inch diameter fluidised bed unit at 700°-750°C, the reducing gas stream containing steam, hydrogen and nitrogen in the ratios of 13:3:30 by volume. This ratio of steam to hydrogen ensured that the reduction of iron oxides would not proceed beyond the magnetite (Fe_3O_4) phase.

Both dry and wet magnetic separations were applied to the magnetised product, but only small upgrading of iron, titanium and vanadium was obtained.

Best results are given in Table 13.

Table 13.

	Total wt. per cent	Distribution of components per cent			Analysis per cent		
		Fe	Ti	V	Fe	Ti	V
Magnetic portion	48	63	37	68	45·4	3·6	0·54
Non-magnetic portion	44	31	59	25	24·1	6·4	0·22
Fine dust loss	8	6	4	7	27·0	2·4	0·33

The above results would indicate that worthwhile concentration of weathered ore was unlikely by ore dressing methods, and thought must be given to the possibility of treating this portion of the deposit as mined, i.e. without preliminary concentration.

Application of Reduction/Acid Leaching Process.

(1) Original Ore—Following earlier promising results from acid leaching of reduced magnetic concentrate, a possible process for treating of this concentrate has been outlined (Fig. 2). The process incorporates recovery of metallic iron powder by hydrogen reduction of ferrous chloride, as described in the Alberta Research Council's (Canada) process for treating low grade iron ores. Vanadium is supposed to be recovered as V_2O_5, and the final residue could be considered as a titanium oxide product.

After further tests on individual stages of the process, a laboratory scale check of the complete process was made, where two 600g batches of concentrate were treated. One batch (MR5) was ground to minus 35 mesh and the other (MR6) to minus 100 mesh Tyler before reduction.

The results are shown in Tables 14 to 18.

One of the objectives of these tests was to provide a sufficient quantity of the final residue for further tests on its possible upgrading into a high grade TiO_2—product for pigment manufacture.

For pigment manufacture, the content of vanadium in such a product should preferably be less than 0.3 per cent V_2O_5, hence in this trial, a second stage of salt-roasting and water leaching of vanadium was applied to yield a final residue with as low a vanadium content as possible.

Actual trial residues, after double vanadium extraction, contained 0.25 per cent and 0.32 per cent V_2O_5. As seen from the calculated composition of final residues (Table 17), silica is the major impurity to be removed to upgrade the residues as a TiO_2 product. Part of this silica would be in the form of silicate minerals.

Table 14.

Reduction/Acid Leaching of Original Ore Concentrate.
Weight Recoveries at Each Stage.

Test	MR5	MR6
Size of feed, Tyler mesh	Minus 35	Minus 100
Recoveries, per cent of feed—		
Reduced concentrate	80	77
Acid leached residue	16·7	14·7
Salt roasted and water leached residue	14·0	12·4
Re-roasted and leached residue	14·0	11·3

Table 15.

Reduction/Acid Leaching of Original Ore Concentrate Test MR5.

Analyses and Recoveries at Each Stage.

	Analyses			Recoveries		
	Fe	Ti	V	Fe	Ti	V
	per cent			per cent of the content in the feed		
Concentrate	61·3	6·2	0·77	100	100	100
Reduced concentrate	75·4	7·4	0·96	98	95	99
Acid leached residue	4·7	33	4·5	1·3	89	97
First salt-roast residue	4·8	35	0·74	1·1	79	13
Final salt-roast residue	4·7	34·5	0·14	1·1	78	2·5

Table 16.
Reduction/Acid Leaching of Original Ore Concentrate Test MR6.
Analyses and Recoveries at Each Stage.

—	Analyses			Recoveries		
	Fe	Ti	V	Fe	Ti	V
	per cent			per cent of the content in the feed		
Concentrate	61·3	6·2	0·77	100	100	100
Reduced concentrate	72	7·0	1·0	98	87	100
Acid leached residue	3·5	32	5·0	0·8	76	95
First salt-roast residue	3·7	35	0·71	0·75	70	11
Final salt-roast residue	3·7	35	0·18	0·7	64	2·6

Table 17.
Reduction/Acid Leaching of Original Ore Concentrate.
Calculated Composition of Final Residue.

Test	MR5	MR6
	per cent	per cent
Ferric oxide, Fe_2O_3	6·7	5·3
Titanium oxide, TiO_2	57·5	58·3
Vanadium pentoxide, V_2O_5	0·25	0·32
Silica, SiO_2	23·2	23·8
Remainder	12·3	12·3

Table 18.
Reduction/Acid Leaching of Original Ore Concentrate.
Efficiency at Each Stage.

Test	MR5	MR6
	per cent	per cent
Reduction stage—iron oxide reduced to metal	99	99
Acid leaching stage—proportions dissolved—		
Fe	99	99
Ti	6	13
V	2	5
Salt-roast and water leaching stage—vanadium extracted—		
1st roast	87	88
2nd roast	11	9
Total	98	97

No significant difference in behaviour throughout the process between samples MR5 and MR6 was apparent. Ferrous chloride crystals were prepared by evaporation of the acid leach liquors.

Analyses showed that Fe metal prepared by hydrogen reduction of ferrous chloride crystals would contain approximately 1 per cent titanium, 0.5 per cent acid insoluble (SiO_2) and a negligible amount (less than 0.1 per cent) vanadium.

Vanadium oxide was recovered from the water-leach solutions after salt-roasting of acid-leach residues. By double salt-roasting, 97 per cent of vanadium was extracted at that stage, and good recoveries were obtained by acid hydrolysis of the water solution. Part of the "red cake" so obtained, was purified by re-precipitating as ammonium vanadate, yielding on ignition V_2O_5 of high purity.

Final residues, after vanadium extraction, contained:—

	per cent
TiO_2	58.0
Fe_2O_3	6.0
V_2O_5	0.3
SiO_2	23.0
other gangue materials	12.7

Attempts were made to upgrade these residues as TiO_2 product by physical means. Screening into size fractions indicated that TiO_2 was slightly enriched in the minus 200 mesh fraction, and silica correspondingly depleted. The difference was, however, not sufficient to be useful. Attempts to effect separation magnetically or electrostatically, were also unsuccessful.

Some titanium oxide solubility tests were made on the residues in order to examine their suitability for direct use in a sulphuric acid pigment process. These tests indicated that only about 30 per cent of the TiO_2 would be acid soluble. The residue would, therefore, appear to be useful only for the chlorination route of pigment manufacture. Although relatively low grade for this purpose the low iron content is one point in its favour.

(2) Weathered Ore—Consideration was given next to the possibilities of applying the above process (Fig. 2), directly to weathered ore without prior concentration.

Results are summarised in Table 19.

Table 19.
Reduction/Acid Leaching of Weathered Ore.
Analyses and Recoveries at Each Stage.

	Analyses			Recoveries			
	Fe	Ti	V	Total weight	Fe	Ti	V
	per cent			per cent of the content in the feed			
Head sample	34·9	4·8	0·40	100	100	100	100
Reduced ore	38·4	5·0	0·42	86	97	90	90
Acid leached residue	3·0	8·1	0·66	52	4·5	88	86
Salt roasted residue	n.d.	n.d.	0·50	55	n.d.	n.d.	69

n.d. = not determined.

The results were disappointing in respect of vanadium recovery. Further work is required to determine whether a reasonable extraction could be obtained by varying the salt roasting conditions.

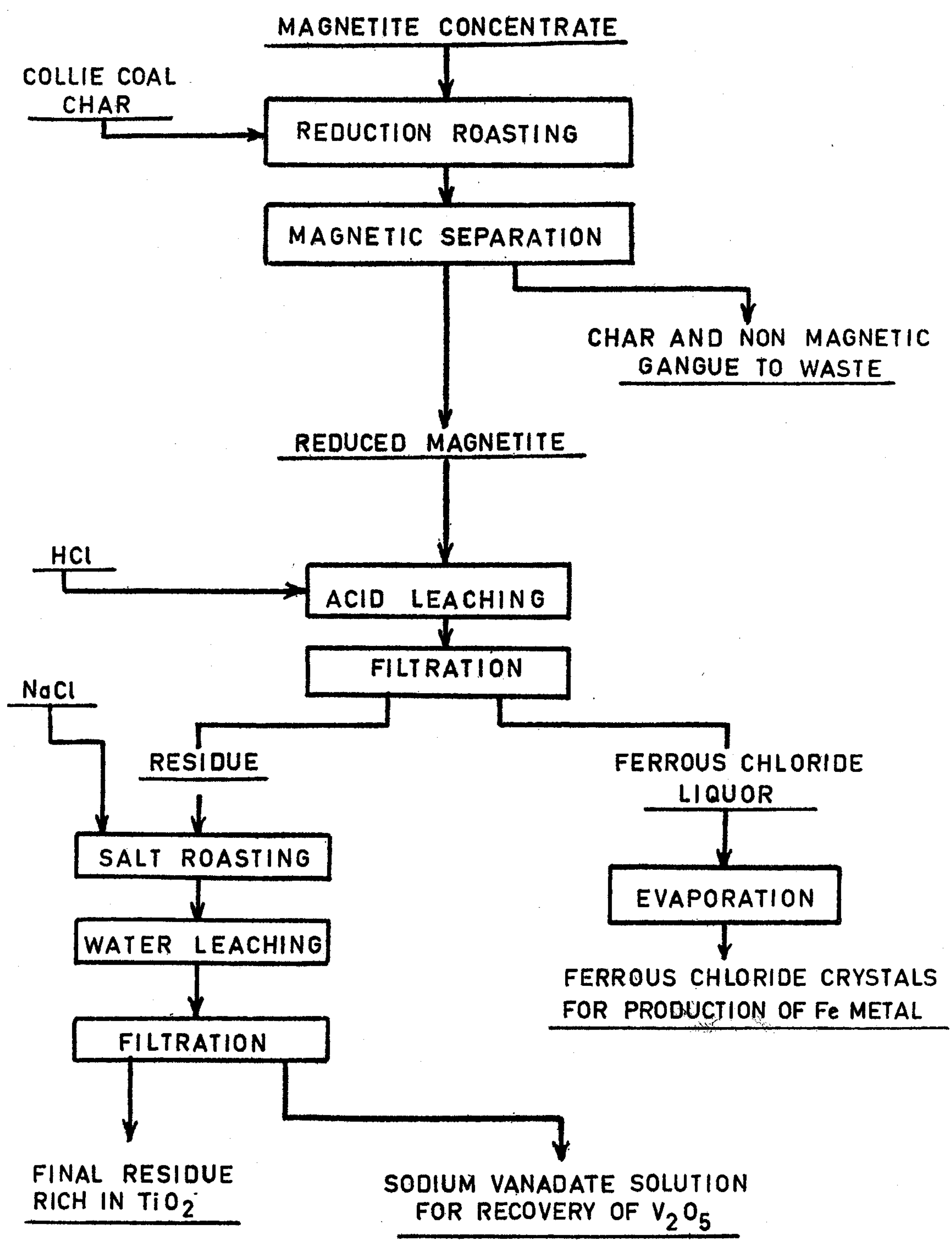
Sulphuric Acid Baking of Weathered Ore.—Earlier work had shown that vanadium could be extracted from weathered ore by baking with sulphuric acid, followed by dilute acid or water leaching.

A more comprehensive program of tests was set up to establish the necessary quantity of acid, the temperature required for baking, and whether vanadium could be made soluble selectively over other components

This procedure, however, was found unlikely to be useful commercially since good recoveries were obtained only with quantities of sulphuric acid close to 1 unit weight of acid to 1 unit weight of

FIGURE .2.

REDUCTION/ACID LEACHING PROCESS



ore. At 80 per cent vanadium extraction, over 50 per cent of the total weight of ore was converted to soluble sulphates, hence vanadium recovery in pure form from the solution would be a further problem.

Lightweight Aggregate for Concrete.

The growth of the use of lightweight aggregate in the building industry has underlined the necessity of establishing an adequate source and processing technique for raw materials available in this State.

The bench scale work of Fuel Technology Division established that the shales of Armadale-Cardup area have bloating properties.

The initial pilot plant tests were carried out by the Division in liaison with the Fuel Technology Division in 1963, on a crushed sample of bloating shale from Hawker Siddeley's quarry in the above area.

The raw material had been analysed and checked for bloating characteristics by the Fuel Technology Division.

During these tests, reported in the Annual Report for 1963 by the Fuel Technology Division, the shale exhibited a high degree of bloatability at 1200° C., but agglomerated into sausage-like mass, rendering the kiln inoperable. Operation at slightly reduced temperature stopped both bloating and agglomeration.

A sponsored project consisting of subjecting bulk samples of pelletised clay to bloating conditions in the rotary kiln was carried out by the Division in 1964, and reported in the Annual Report for that year.

In this work, attempts to induce satisfactory bloating in rotary kiln by using straight-forward techniques were largely unsuccessful, due to the tendency of the pellets to ball up in the kiln when at bloating temperature.

Wide variation of the kiln rotating speed and inclination, of the kiln atmosphere, of the pellet size and feed rate, failed to produce a satisfactory product without agglomeration.

In the light of the failure to master, on a pilot plant scale, the manufacture of a satisfactory aggregate by straight-forward techniques, and in view of the sponsored work being stopped at the sponsor's request, further investigations were considered warranted.

The raw materials tested, possessed a narrow bloating range, of the order of 50° C., and as such would normally be considered as unsuitable for processing in a rotary kiln (Ref.: U.S. Bur. Min. Dep. Inv. NN 6061, 6313, 6614 and Inform. Circ. No. 8122 and 8228).

However, before entirely ruling out these raw materials as a source of aggregate made in a rotary kiln, the evaluation of the effectiveness of spraying refractory powdered material into the hot zone of the kiln was considered necessary. This technique had been devised in the U.S.A. and had been used with success by C.S.I.R.O. when testing Victorian clays. Investigations into applicability of such a technique were commenced early in 1965.

The rotary kiln, used in this work is shown diagramatically in Figure 3.

The kiln, equipped with "Major" oil burner, was fed by a standard "Syntron" Vibration Feeder handling pellets at a controlled rate. A variable speed drive enabled the kiln speed to be set between limits of one and twenty RPM. Provisions were available for altering the inclination of the kiln and for varying the kiln atmosphere by adjusting the oil burner or stack damper.

On the equipment for the injection of refractory powder, the screw feeder was driven by a variable speed motor, which allowed variation of the rate of injection. The discharge probe was water cooled, and so mounted that it could be directed into the hot zone of the kiln. Compressed air at 15 p.s.i. pressure was used to introduce powder into the kiln.

The raw material for these trials was a bulk quantity of shale obtained from a Perth firm, and reported to have been taken from the Mundijong area in the vicinity of the railway cutting, thus being likely to be from an extension of the Cardup series.

However, in one of the preliminary runs, chips of shale, used in previous trials, i.e., from the Hawker Siddeley's quarry, were used with good results.

The shale was crushed to minus 14 mesh Tyler and then pelletised in a rotary 11 inch diameter drum. The only pelletising additive used was water. The pelletising drum was operated so as to give a pellet size of from ¼ inch to ¾ inch diameter.

Since moist pellets invariably decrepitated to fines when introduced into the rotary kiln the pellets were air dried before feeding into the kiln. The pellets retained, in this way, most of their physical strength and little fritting occurred during slow drying.

In the preliminary trials, finely ground silica (washed river sand) was used as the refractory material for controlling agglomeration. A brief trial with finely ground silica separated from lime sands by electrostatic separation gave good results.

The rate of feeding the pellets into the kiln was varied widely to find optimum conditions. The kiln atmosphere was maintained from neutral to slightly reducing, so that the flue gas exhausted from the stack showed a faint black smoke.

The bulk density of the product varied from 34.1 to 47.6 lb./cu. ft.

To ascertain whether the aggregate produced from the above tests was actually suitable for lightweight concrete, samples of the products of some of the best runs were submitted to the Materials Testing Laboratories, East Perth, for evaluation.

The more important results, selected from their report, are listed in Table 20.

The results of these preliminary tests were considered to be sufficiently promising, and a larger scale test was carried out later in the year.

For this test, approximately 1 ton of shale from the previous source was crushed, screened and pelletised as for preliminary runs. The main bulk of the pellets prepared were in the minus ¾in. plus ⅓in. range.

The kiln firing was adjusted to give a flue gas analysis at the chimney inlet of near to 3.0 per cent oxygen. The resultant longer burner flame produced a kiln hot zone generally coinciding with the No. 6 thermocouple point, instead of No. 7 thermocouple position of previous runs. The temperature readings on this thermocouple were between 1,170° and 1,250° C. whereas the optical pyrometer readings on the hottest spot in the kiln were between 1,195° and 1,260° C. The test was separated into 11 periods. At the end of each period, one or more of the kiln variables were altered for testing purpose.

The kiln was set at a slope of ½in. in 2ft. and was operated at 8 RPM, these conditions being not varied for the whole run.

In order to test the suitability of refractory materials other than silica as an agglomeration inhibitor, ground kaolinitic clay was injected.

The results of this test can be summarised as follows:—

(a) Silica injected at a rate equivalent to 2 per cent of the weight of raw material (pellets) prevented agglomeration of bloated pellets.

(b) Kaolinitic clay was found to be not a satisfactory substitute for silica in preventing agglomeration of bloated pellets in the kiln.

(c) Satisfactory results were achieved whilst a pellet feed rate of 100 lb. per hour (air dried pellets) was employed for most of the trial, and for short periods rates of 160 lb. and 240 lb. per hour were tried without noticeably influencing kiln performance.

The rate of 100 lb. per hour is well in excess of comparable rates, on a feed-rate-per-kiln-volume basis, reported for commercial kilns.

(d) The use of a slightly oxidising kiln atmosphere did not result in any appreciable difficulty in process operation, and rendered kiln control easier.

Tests to date have shown that commercially potential lightweight aggregate for concrete can be produced from chips or pelletised fines of the Cardup Series shales by processing in rotary kiln using special technique, i.e. the injection of fine silica into the hot zone of the kiln.

Table 20.

Some results of light weight aggregate evaluation by Materials Testing Laboratories, East Perth.

Unit Weight of Aggregate by A.S.T.M. C 29–60

Sample	Unit weight, lb./cu. ft.
Run 5 (+ ½ in.)	30·6
Run 5 (— ½ in. to + ¼ in.)	30·4
Run 7 (— ¼ in.)	34·8

Water Absorption by Aggregate according to A.S.T.M. C 127–59

Sample	Period of immersion	Absorption per cent
Run 5 (— ½ in. to + ¼ in.)	10 min.	5·3
	30 min.	5·4
	1 hour	6·4
	4½ hours	7·8
	22 hours	11·5

Details of the Test

(a) Grading of sand used—

B.S. Sieve	per cent
Minus 14	100·0
Minus 25	95·1
Minus 52	27·3
Minus 100	2·1

(b) Lightweight aggregate used—
Product from Run 5 (+ ½ in. and — ½ in. to + ¼ in.).
Product from Run 7 (— ¼ in.).

(c) Aggregate and cement ratio .... 3·73 by weight

(d) Lightweight aggregate and sand ratio 0·85 by weight

(e) Total water and cement ratio .... 0·71 by weight

(f) Unit weight of concrete .... 98·4 lb./cu. ft

(g) Compressive strength of 6 in. x 6 in. x 6 in. concrete cubes—

Age (days)	Strength (p.s.i.)
7	1880
28	2800

The use of pellets, with the need for fine crushing and pelletising for their manufacture, leads to increased production costs. This is, however, considered justified since the Cardup deposits are markedly banded, the variable composition of the bands resulting in variable bloating properties. Crushing and mixing prior to pelletising produces a more uniform raw material, which expands to give an aggregate of uniform pore size, and hence a uniform physical strength.

The actual capacity of the kiln, and related economic factors of production are still to be evaluated by further work which is to be continued in 1966.

The Effect of the Method of Preheating of Lime Sand on its Electrostatic Beneficiation.

In earlier investigations it was found that preheating of the sand was necessary if efficient separation of calcium carbonate and silica was to be achieved. It was also observed that the degree of, and technique used in, the preheating have a profound influence on separation, in some instances the sand having been made completely unresponsive to electrostatic separation.

A series of tests comparing preheating temperatures with the efficiency of separation was started near the end of the year.

Good separation was obtained for preheating temperatures up to 300°C. Above 300°C. separation began to be impaired, and if heated above 400°C., the sand was rendered inert to electrostatic separation, even if the temperature was lowered again.

These findings emphasised that careful design and operational control are required in the preheating step—particularly in direct heating systems where flame impingement on to the sand could be a problem.

This temperature-caused fall-off in susceptibility to electrostatic separation was shown to be not peculiar to lime sand, but also applied to other $CaCO_3$-SiO_2 separations. A synthetic mixture of crushed marble chips and quartz was found to be separated efficiently when heated to 100°C., but failed to respond when heated to 400°C.

Evidence to suggest that the contact potential existing between silica and carbonate particles is of importance to the fundamentals of the separation, was obtained in tests where quartz and carbonate particles were passed through the electrostatic field both as a mixture and as individual components. Quartz responded fully to the electric charges when passed in a mixture with carbonate, the mixing being effected only 10 seconds before passing through the separator, but failed to respond when passed on its own through the field.

Investigations into Brick Discoloration.

At the request of a local clay brick manufacturing firm, investigations, (lasting nearly 6 months), were carried out into the cause and possible elimnation of occasional discoloration of pale-coloured bricks, thought to be caused by variations in the kiln firing conditions.

A considerable number of drying, firing and other tests were made under varying conditions in the Division's furnaces as well as in the commercial kiln itself.

As a result of these investigations it was established that the occasional discoloration of bricks was not caused by the firing conditions of the kiln, but by other factors, which could be eliminated by suitable arrangements and operation.

Investigations into Calcination of Local Limestones.

An evaluation of the influence of kiln variables on the calcination of various local limestones in the rotary kiln of the Division, was requested by a local firm.

Altogether four limestone varieties from different local deposits, were investigated.

As a result of this work it was indicated that limestones from different localities require somewhat different kiln operating conditions in order to produce lime with optimum reactivity, degree of calcination, etc.

Recarbonation of Hydrated Lime.

Towards the end of 1964, investigations requested by a local industry were commenced into recarbonation of hydrated lime by dry gas-solid contact. This work was carried over into and completed in 1965.

Following this, and the review and appraisal made by the Division of the more important methods of manufacture of calcium carbonate, a request was received during the year from the same firm for investigation of the production of calcium carbonate from hydrated lime by wet gas-solid contact.

The investigations yielded satisfactory results, and a batch of the product was handed over to the sponsor for practical tests of its use.

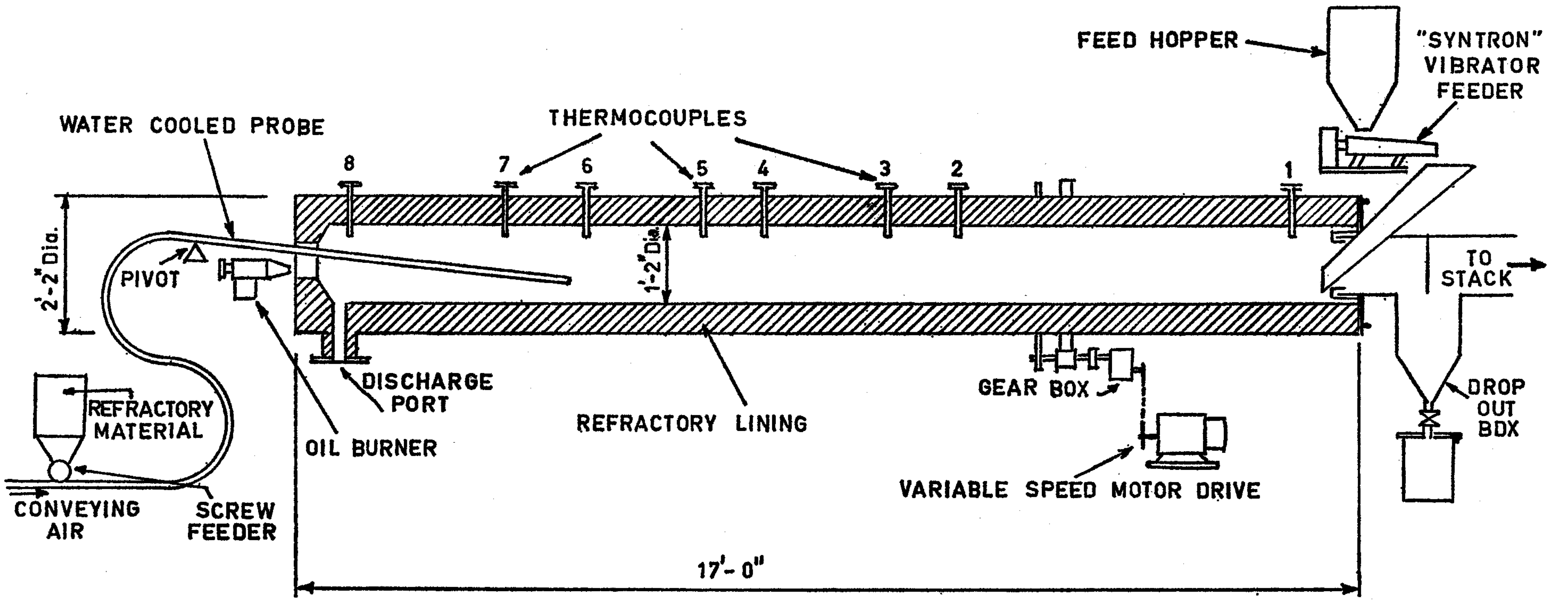
Other Work.

A number of smaller tasks werre carried out by the Division by request, among them:

(a) About 150 lb. of leucoxene were ground to a minus 200 mesh size. The contamination of the product by metallic iron grinding was checked and found to be less than 0.1 per cent.

(b) In response to a request from the P.W.D. Engineering Research Section, a quantity of Ord River rock was screened into five size fractions, using pilot plant equipment.

(c) A request for assistance in commissioning an electrostatic beach sand beneficiation plant resulted in several trips to the plant by a research officer and a laboratory technician.



PILOT PLANT ROTARY KILN

FIG. 3.

General.

(1) A discussion with the Metallurgical Committee of the Chamber of Mines of W.A. was held in Kalgoorlie on 12th July attended by the Director, Dr. L. W. Samuel, and two officers of the Division, Dr. S. Uusna and Mr. R. Canning.

The present situation regarding the work on sulphur recovery from roaster gases at Kalgoorlie. and possible further work in this field, were discussed.

(2) Technological advice and assistance in form of bench and pilot plant apparatus, were given to other Government Departments, to the Perth Royal Mint and to numerous private industrial and mining interests.

(3) The paper entitled: "A New Process for Upgrading Ilmenitic Mineral Sands" prepared by the staff of the Division and presented at the 1964 Annual Conference of the Australasian Institute of Mining and Metallurgy, was amended and edited for publication. It was published in June issue (No. 214), 1965, of the Aus. I.M.&M. Proceedings.

(4) The Divisional Chief, Dr. S. Uusna, was appointed for three years a member of the Board of Management (a director) of the Australian Coal Industry Research Laboratories Ltd. (a company limited by guarantee and having a share capital) in Sydney. to represent on the Board the State of Western Australia.

FOODS, DRUGS, TOXICOLOGY AND INDUSTRIAL HYGIENE DIVISION.

The work of this Division in 1965 consisted largely of chemical and some physical examinations for the Departments of Agriculture, Police, Public Health and Public Works, 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 the general public.

The staff of the Division during the year numbered 15 officers, comprising 11 qualified chemists, 3 technicians (in course of qualifying) and one laboratory assistant. One technician passed final qualifying examinations at the end of 1965, altering the number of chemists to 12 and of technicians to 2.

Laboratory accommodation remained at the same level as at the end of 1964, but building extensions to the Division are expected to be completed during 1966, and it is expected that some extra accommodation will be available before the middle of that year.

3,611 samples were received during the year. Although the increase over the number for 1964 is only 100, this represents a 50 per cent. increase over the numbers being received five years ago, e.g. 2,436 samples in 1960.

A broad outline of the variations in numbers during the period 1961-65 is indicated in the following classification Table 21, (selected sample groups):

Table 21.

Class	1961	1962	1963	1964	1965
Foods—total	815	815	656	773	720
milks	437	574	382	604	588
Exhibits—alcohol	315	331	378	433	458
Human toxicology	388	611	649	604	711
Industrial hygiene	335	446	233	349	262
Miscellaneous	710	608	1,010	883	1,053
Pesticides	160	231	210	175	153
Oil seeds	174	....	342	143	265
Pollution surveys—					
Swan River	178	128	128	145	109
Bunbury	50	50	48	48	48
Total samples received	2,901	3,177	3,279	3,511	3,611

Table 22 shows the source and condensed description of samples received during 1965.

Table 22.
Foods, Drugs, Toxicology and Industrial Hygiene Division.

	Agriculture Department	Department of Air	Hospitals	Labour Department	Milk Board	Mines Department	Police Department	Public	Public Health Department	Public Works Department	Swan River Conservation Board	Tender Board	Western Australian Government Railways	Other Commonwealth Departments	Other State Departments	Other	Total
Food—																	
Apples	10	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	10
Cheese	24	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	24
Fish	....	....	....	....	....	....	....	....	26	....	....	....	....	....	....	1	27
Fruit	....	....	....	....	....	....	....	....	10	....	....	....	....	....	....	....	10
Milk	....	1	....	....	579	4	1	....	3	....	....	....	....	....	....	....	588
Sugar	....	....	....	....	....	....	....	....	15	....	....	....	....	....	....	....	15
Wine	15	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	15
Various	5	....	....	6	....	2	....	1	19	....	....	....	....	....	....	....	33
Industrial Hygiene—																	
Air	3	....	....	....	....	10	....	3	17	....	....	....	....	....	....	....	33
Blood	....	....	....	....	....	....	....	1	13	....	....	....	....	....	....	....	14
Urine	....	....	2	45	....	....	....	95	41	....	....	....	13	....	....	....	196
Various	....	....	....	....	....	....	....	....	15	....	....	....	....	....	....	....	15
Miscellaneous—																	
Building materials	....	....	....	....	....	....	....	....	15	....	....	....	....	....	....	1	16
Cotton seed	12	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	12
Criminal cases	....	....	....	....	....	....	39	....	....	....	....	....	....	1	....	....	40
Detergent	....	....	....	....	....	....	....	....	....	....	....	67	....	....	....	....	67
Explosives	....	....	....	....	....	18	....	....	....	....	....	....	....	....	....	....	18
Linseed	211	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	211
Oxygen	....	35	....	....	....	....	....	....	....	....	....	....	....	....	....	....	35
Pesticide	267	....	....	....	....	....	....	6	2	62	....	....	....	....	....	....	337
Plants	53	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	53
Safflower	54	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	54
Soil	....	....	....	....	....	....	....	....	....	10	....	....	....	....	....	....	10
Tallow	....	....	....	....	....	....	....	15	....	....	....	....	....	....	....	....	15
Water	....	....	2	....	....	4	....	2	47	....	....	....	....	....	1	....	56
Various	19	1	8	....	....	5	6	19	33	30	....	3	....	4	3	....	131
Pollution—																	
Effluents	....	2	....	....	....	....	....	....	....	1	23	....	....	....	....	....	26
Water	....	....	....	....	....	48	....	....	....	48	109	....	....	....	....	....	205
Various	....	....	....	....	....	....	6	....	....	....	1	....	....	....	....	....	7
Toxicology—																	
Human—																	
Toxicology	....	....	1	....	....	....	708	....	2	....	....	....	....	....	....	....	711
Sobriety	....	....	....	....	....	....	175	....	....	....	....	....	....	....	....	5	180
Traffic death	....	....	....	....	....	....	278	....	....	....	....	....	....	....	....	....	278
Specimens from patients	....	....	60	....	....	....	....	7	66	....	....	....	....	....	....	....	133
Animal	27	....	....	....	....	....	2	5	2	....	....	....	....	....	....	....	36
	700	39	73	51	579	91	1,215	154	326	151	133	70	13	5	4	7	3,611

(12)—25843

Foods

A total of 720 samples of food of various kinds was received and examined during the year. 579 of these were samples of cows' milk submitted by the Milk Board of Western Australia.

Of this number 224 were samples seized by Inspectors for checking against the chemical standards required by Regulations under the Milk Act. 5.4 per cent of these samples contained less than the legal minimum of milk fat (3.2 per cent), and 50.6 per cent contained less than the legal minimum of solids not fat (8.5 per cent), while 41.6 per cent of the samples failed to comply with the legal standard for freezing point of milk (0.540 degrees Centigrade below zero). The lower proportion of samples which failed to comply with the standards for fat, solids not fat and freezing point shows an improvement on the figures for 1964.

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	2.7
3.00-3.19	2.7
3.20-3.49	11.6
3.50-3.74	24.5
3.75-3.99	17.4
4.00-4.99	34.4
More than 4.99	6.7
	100.0

Milk Solids not Fat

per cent in sample	per cent of total samples
Less than 8.00	3.6
8.00-8.24	12.5
8.25-8.49	34.5
8.50-8.74	38.2
8.75-8.99	8.5
More than 8.99	2.7
	100.0

Freezing Point

Degrees C below zero	per cent of total samples
Less than 0.510	0.5
0.510-0.519	Nil
0.520-0.529	2.3
0.530-0.539	38.8
0.540-0.550	47.9
More than 0.550	10.5
	100.0

In presenting the above figures it is emphasised that these were Inspectors' samples for which there was *prima facie* evidence of their not complying with the legal standards.

An additional 326 samples of milk were also submitted for the determination of freezing point only, and 28 samples for analysis for fat and total solids in connection with the Milk Board's Improvement Scheme. The distribution of figures for the two groups is shown in the following Tables:—

Freezing Point—326 samples

Degrees C below zero	per cent of total samples
0.510-0.519	0.6
0.520-0.529	1.0
0.530-0.539	56.5
0.540-0.550	41.9
More than 0.550	Nil
	100.0

Milk Fat—28 samples

per cent in sample	per cent of total samples
Less than 3.00	10.7
3.00-3.19	Nil
3.20-3.49	3.6
3.50-3.74	32.1
3.75-3.99	17.9
4.00-4.99	32.1
More than 4.99	3.6
	100.0

Milk Solids not Fat—28 samples

per cent in sample	per cent of total samples
Less than 8.00	3.6
8.00-8.24	28.6
8.25-8.49	17.9
8.50-8.74	32.1
8.75-8.99	10.7
More than 8.99	7.1
	100.0

24 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 92 per cent contained more than 50 per cent fat calculated on a moisture free basis, compared with 48 per cent of the samples which complied with this standard in 1964.

26 samples of smoked fish submitted by the Public Health Department were examined for artificial dyes. One sample was found to be coloured with Yellow 2G and one with Yellow RFS which, although classed as "permitted colouring", may not be added to smoked fish.

14 samples of coloured sugar used for making a popular line of confectionery were also analysed to determine the nature of the colouring. Two samples contained a prohibited artificial dye, namely Red 2G and Orange 1.

Another sample of sugar whose "sharp acid taste" was the subject of complaint, was found to be contaminated with a small quantity of citric acid, which while not harmful, rendered the sugar unsuitable for a number of domestic purposes.

26 pieces of marzipan comprising 10 different types of "fruit" were examined because of their unusual hardness. Analysis did not disclose any reason to suggest that they were not genuine marzipan or that they did not comply with Food and Drug Regulations. It was considered that the hardness may have been caused by a slight alteration in concentration of a normal constituent.

Further work was conducted by the Department of Agriculture on the control of "scald" in apples and 9 samples which had received different experimental treatments with ethoxyquin were analised to determine the ethoxyquin contents of the pulp and the skin respectively.

One other sample of apples was submitted to determine lead and arsenic residues from a pesticide spray suspected of having caused brown skin "lesions" on the fruit.

Samples of bread submitted by the Department of Labour were examined for compliance with Regulations under the Bread Act, while samples described as "Bread Rolls" were analysed to determine whether they were in fact bread as defined in the Bread Act.

A sample of canned fish when examined was quite normal in flavour and odour and the can showed no sign of corrosion, although it was stated that other similar cans showed evidence both of "gas" and corrosion, suggesting deterioration of the contents. On the other hand some samples of canned "luncheon meats" with discoloration of the meat and container showed distinct evidence of "sulphide staining".

A sample of foreign material said to have been found in canned prunes was identified as a piece of jute which had probably originated from the bagging and had travelled with the prunes through the subsequent processing.

A sample of soya bean flour which was the subject of complaint as to quality was found on examination to be coarsely ground and to be contaminated with wheat flour.

Three samples of flavoured milks were analysed as a check on compliance with the fat content required by the Food and Drug Regulations; one milk sample was examined to identify the nature of its peculiar odour, and another was analysed for poisons, without result, because of its suspected association with a complaint of illness.

Microscopic examination of samples of sago and tapioca revealed that some confusion existed as to what in fact was sago and what was tapioca.

Suspected associations of particular samples of foods with complaints of illness led to the examination for poisons of bread, tea, meat pie, tomato juice, sugar and cauliflower, all with negative results.

A sample of meal for use in the manufacture of sausages was analysed to determine the amounts of preservative and starch present in the meal; and a sample described at "green olive oil" was submitted to ascertain if it was a satisfactory substitute for olive oil of the standard prescribed in the Food and Drug Regulations.

5 samples of butter were analysed for the Dairying Division, Department of Agriculture in connection with their work on the reaction, pH, of butter serum, and the Horticulture Division again submitted samples of wine which had been made from grapes subjected to experimental spraying with different insecticides, in order to determine the levels of insecticide present in the finished product.

Human toxicology

Samples were received from approximately 345 cases of sudden death which were the subject of police examination. 155 cases were as a result of "traffic accident", while 145 cases, comprising 711 exhibits, were submitted for examination for poisons or other physiologically active drugs.

In 41 cases no poison or drug was detected while in 104 cases a poisonous substance or drug was identified on analysis. Details are listed in Table 23.

Table 23.

Poison or Drug	No. of Cases
Carbon monoxide	24
Pentobarbitone	26
Amylobarbitone	14
Quinalbarbitone	11
Barbiturate (unidentified)	13
Carbromal	13
Alcohol	4
Chlorpromazine	3
Asperin	2
Chloral	2
Librium	2
*Various, one of each	15
Negative	41

* Arsenic, barbitone, bromoureide (unidentified), bromvaletone, butobarbitone, insidon, lysol, petrol, phenacetin, phenobarbitone, quinidine, quinine, stelazine, strychnine, talbutal.

As in previous years it was noted that carbromal was usually associated with pentobarbitone, their presence in viscera being derived from ingestion of "Carbrital".

In 63 of the 121 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 23 of these cases, and 0.05 to 0.14 per cent in 26 cases.

From another 43 cases of sudden death other than "traffic accident", blood samples were analysed for alcohol, making a total of 164 such cases of sudden death where the blood alcohol figure was determined as a routine procedure. The distribution of the blood alcohol figures is shown in Table 24, from which it will be observed that in 37 cases, i.e. 22.5 per cent of the total, the blood alcohol figure was 0.15 per cent or greater.

Table 24

Alcohol per cent	No. of Cases
Negative	77
Less than 0.05	19
0.05 - 0.14	31
0.15 - 0.25	26
More than 0.25	11
	164

Blood Alcohol (Traffic)

278 samples of blood and/or urine were received in connection with investigations into fatal traffic accidents. 155 of these were "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 25.

Table 25

Alcohol per cent	Drivers	Passengers	Pedestrians
		number involved	
Negative	40	14	14
Less than 0.05	8	7	1
0.05 - 0.09	4	5	—
0.10 - 0.14	11	3	1
0.15 - 0.20	13	1	6
More than 0.20	13	6	8
	89	36	30

The above Table shows that 29 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 19 per cent and 47 per cent respectively.

The proportion of drivers is similar to that noted in 1964, namely 28 per cent, but in regard to passengers and pedestrians the figures show an increase on the 1964 proportions of 12 per cent and 17 per cent respectively.

Voluntary Blood Alcohol tests

175 samples of blood were submitted by the Police Department and 5 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 an offence, had excercised 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 26, the figures being the alcohol content of the blood at the time of the alleged offence, calculated as prescribed by the Blood Alcohol Test Regulations.

Table 26

Alcohol, per cent	No. of Cases
Less than 0.15	9
0.15 - 0.20	64
0.21 - 0.25	65
0.26 - 0.30	31
More than 0.30	11
	180

From accused persons who pleaded not guilty, 81 samples of blood were sufficient in quantity to be analysed by two chemists, making a total of 261 analyses in connection with this work.

It was noted, as a matter of interest, that in 72 cases, i.e. 40 per cent of those who submitted blood for analysis, a plea of guilty was entered at the Court before the result of analysis was known. In nearly all of these cases however the blood alcohol figure was greater than 0.15 per cent, as shown in Table 27.

Table 27

Alcohol, per cent	No. of Cases*
Less than 0.15	4
0.15 - 0.20	26
0.21 - 0.25	23
0.26 - 0.30	14
More than 0.30	5
	72

* Plea of guilty prior to analysis.

An examination of the time at which the offence of "drunken driving" occurred showed that the greatest number of offences were between 10 p.m. and 11 p.m., followed by a lesser number in the period 11 p.m. to midnight, then a less but fairly uniform number through the hourly periods from 4 p.m. to 10 p.m. The distribution of the times of occurrence of the offence is given in Table 28.

Table 28

Time of Occurrence	No. of Cases
p.m.	
4-5	16
5-6	17
6-7	14
7-8	13
8-9	15
9-10	15
10-11	37
11-m.n.	24
a.m.	
m.n.-1	9
1-2	3
2-3	5
3 a.m. - 4 p.m.	12
	180

Specimens from Patients

133 samples were received under this classification. Approximately 50 specimens of blood and 60 of urine together with a small number of gastric contents, hair, nails etc. 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 Table 29.

Table 29

Type of analysis	Number
Arsenic	19
Copper	27
Lead	26
Thallium	7
Alcohol	5
Amphetamine	22
Barbiturate	21
Nitrous oxide	8
Strychnine	3
Thiocyanate	2
D.D.T.	1
Morphine	1
Phenmetrazine	1
Promazine	1

As in previous years samples of urine were analysed for copper in connection with clinical investigations of Wilson's disease, in which high levels of copper excretion are encountered.

Animal Toxicology

32 samples were received for examination in connection with 17 cases of suspected poisoning of animals. In 11 of these cases no poisonous substance was detected on analysis, while there were 2 cases where lead was detected in significant quantity, 3 of strychnine, and one where a trace only of arsenic was present.

8 samples of suspected poison baits were submitted for analysis, but all proved negative.

4 samples of animal liver were analysed for the Animal Health Branch of the Department of Agriculture in connection with investigations into Vitamin A deficiency.

Industrial Hygiene

250 samples were examined during the year in connection with industrial hygiene investigations.

179 of these were specimens of urine from workers exposed to suspected lead hazard, and were analysed in order to assist clinical diagnosis or as a "screening" to exclude the possibility of undue exposure.

Of these specimens, 151, or 84.4 per cent contained less than 0.08 part per million (milligram per litre) of lead (Pb), 12.3 per cent contained 0.09-0.15 part per million, and 3.3 per cent contained more than 0.15 part per million.

Other specimens of urine examined in connection with possible exposure to hazardous materials included analyses—

(1) for arsenic from pest control operators.
(2) for mercury from workers handling organic mercurial fungicides
(3) for chlorinated hydrocarbons from a person mixing insecticide dusts, and
(4) for phenol and "sulphate ratio" from workers using benzene in varnish "stripping" operations.

Samples of blood were also analysed for lead as an adjunct to the urine analysis in a limited number of cases, while other samples of blood were examined for carboxyhaemoglobin in an attempt to assess exposure to furnace gases.

A sample of biopsy fat from an insecticide worker was examined for chlorinated hydrocarbons. Although only a trace of D.D.T. was detected, an appreciably greater concentration of the metabolite D.D.E. was found to be present.

10 samples of air collected during different operations and at different locations in assay offices were submitted for determination of lead content, while a similar examination was made of air collected during the processes of dry-brushing and burning-off of old paintwork.

During inspections of factory premises where potentially hazardous materials were being used, analyses were made of the ketones, chiefly acetone, in the air of a building where "plastic finishes" were applied; and of the T.D.I. (tolyl di-isocyanate) concentration to which workers were exposed during the manufacture of polyurethane foam products. On other premises air was analysed for "1080" content arising from the commercial manufacture of poisoned oats.

4 inspections were carried out as a result of suspected hazardous working conditions in the holds of cargo ships. Two of these involved spillages due to broken drums of Cyanogas (calcium cyanide) and 15 analyses of air at different locations were carried out to ascertain the degree of hazard and/or to check the effectiveness of the protective measures which had been recommended.

The other two inspections involved o-dichlorobenzene in one case, and a mixture of o-dichlorobenzene and naphthalene in the other. In the first case, inspection showed that no hazard existed, and in the second case the provision of suitable ventilation reduced the contamination of the air to negligible proportions.

Following reports that in some shipments of fumigated wheat the Cyanogas residues exceeded the acceptable tolerance, a limited investigation was carried out for the Public Health Department to ascertain the cause of the unduly slow liberation of fumigant. In a series of tests extending over a period of several weeks it was concluded that the wheat as received for storage did not contain sufficient moisture in the interstitial air to liberate all fumigant from the Cyanogas.

Miscellaneous examinations included analyses of cleaning solutions etc for benzene and toluene, the testing of a petrol-driven air compressor to ascertain whether carbon monoxide from the exhaust was entering the air inlet to the compressor; and the inspection of an area adjacent to stagnant water following complaints of offensive odours from that source.

Pollution Surveys.

(1) Swan River.—The regular surveys of the Swan River were continued in 1965 when 109 samples of river water from normal sampling points were received and analysed for the Swan River Conservation Board.

23 samples of trade effluents from specific factories 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 with the regular summer and winter pollution surveys of the water in the Leschenault Inlet at Bunbury, and 48 samples were collected and analysed in the surveys in January and August, 1965.

(3) Maritime.—Six samples suspected of being oil were received and examined. These were fluids 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 similar substance.

(4) Underground.—Following earlier check analyses which confirmed that an unusual chemical contamination of an underground stream had now persisted for 5-6 years, a Departmental survey was carried out in collaboration with the Public Works Department.

Bore drillings were made at a number of selected sites and depths in order to obtain information on the extent of the contamination in relation to the suspected source of pollution.

47 samples of water from these drillings were analysed for phenolic substances and chloro derivatives of phenoxyacetic acid.

Miscellaneous.

1. Waters.—85 samples were received under this classification.

Five of these were waters analysed as preliminary checks in connection with the underground pollution problem already referred to, while two samples from a Local Authority were examined to determine if well water was subject to pollution from a factory disposal pit some distance away.

One sample from the Fisheries Department and 47 samples from the Public Health Department were submitted for analysis to determine if residues from insecticide sprayings were present in significant amounts.

Two samples of water from household tanks were analysed for a hospital in an attempt to find the cause of heavy metal poisoning in a patient.

28 samples of water were collected and analysed for the Public Works Department in an investigation of the toxicity and persistence of a chemical used for control of aquatic weed. Apart from observations on its effect on vegetation and fish life, it was noted that the concentration decreased very rapidly when the "official" recorded temperature exceeded 90° F.

2. Pesticides.—153 samples classified as pesticides were received and examined during the year. The numbers and variety of the samples are listed in the following Table:—

Pesticides	No. of samples
Weedicides (2,4-D) type)	54
Aldrin (solid)	1
Aldrin (concentrated)	15
Aldrin (diluted emulsions)	48
Dieldrin (solid)	8
Dieldrin (concentrate)	20
Chlordane (concentrate)	1
Endrin (concentrate)	1
Fenthion (concentrate)	1
Various	4

Most of 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 a number of building projects. Frequent sampling was carried out as a check to specification of materials being used for treatment purposes.

Consequent upon the detection of sub-standard material, samples of technical aldrin and aldrin concentrate were also analysed for a pesticide supplier in an endeavour to trace the cause of the trouble.

Although not classified as pesticides, ten samples of soil were also examined to determine the efficiency of application in specific cases.

There was a marked increase in the number of samples of 2,4-D type weedicides submitted by the Weed Control Branch of the Department of Agriculture. 54 samples were received during the year, compared with 30 in 1964, and were analysed at regular intervals as a check on quality of the concentrates.

Samples of technical dieldrin and of dieldrin and chlordane concentrates were analysed for conformity to the specifications required variously by the Agriculture Protection Board and Biological Services Division of the Department of Agriculture.

A sample of endrin concentrate was examined for contamination by dieldrin because of the unexpected detection of the latter on samples of vegetable seeds.

A sample of fenthion (Baytex) concentrate was submitted by the Public Health Department for analysis in connection with proposals under consideration for its use experimentally for control of mosquito larvae.

The need to apply minor element sprays to particular crops led to investigational work being carried out for the Biological Services Division of the Department of Agriculture on the compatibility of mixtures of the insecticides required with copper sulphate solution. Under the conditions of dilution and operation suggested it was considered that the mixing of the sprays was a practical proposition.

3. Criminal.—There was only a slight increase in the number of exhibits received in connection with the investigation of suspected crime.

A large proportion of these, comprising post mortem exhibits, drugs, and miscellaneous exhibits were submitted in connection with suspected abortion resulting in death.

Charred material from a building destroyed by fire was found to contain kerosene, and the fibres of partly-burnt cloth were identified in an endeavour to trace its source.

Cotton waste from a fire of unknown origin was examined to determine the nature of the oil adhering to the fibres.

Samples of paint chips from vehicles, articles of clothing, nail clippings and skin impregnated with dirt and grease were among the exhibits submitted in connection with hit-run accidents during the year.

A water-damaged bank note, suspected of being a forgery, was examined in an attempt to decipher the faint pencilled characters which may have given information as to its origin, and a sample of prepared tea, the exhibit in an alleged attempt "to poison" was found to contain a normal dose of a sedative drug.

4. General. 68 samples of detergents were submitted by the Government Tender Board for consideration and advice as to those most suitable for use in Government Institutions. These varied from the relatively simple synthetic detergents to composite soap powders, laundry adjuncts, liquid soap type cleaners with and without deodorant properties, steam-cleaning compounds, solvent type degreasers, and detergent preparations for highly specialised uses.

Regular testing of "high altitude" oxygen for the Directorate of Quality Control of the Department of Air was continued throughout the year and 35 cylinders of this oxygen were received and analysed for conformity with R.A.A.F. specifications.

The increase in the number of samples of building materials submitted in 1964 for testing for "fire resistance" was not maintained in 1965. Only 16 such samples were examined to assist the Public Health Department in assessing their suitability for use in public buildings.

Two hundred and eleven samples of linseed and 54 samples of safflower seed from the Department of Agriculture were analysed for oil and moisture contents in connection with the Department's variety selection trials.

Samples of lupin seeds were examined for alkaloid content to assist the Animal Health Branch determine their suitability for proposed investigations into lupinosis.

Fifteen samples of tallow were analysed to check their quality against trade requirements, and 2 samples of wool grease were submitted for identification and assay of impurities in order to assist the manufacturer maintain the standard required by his market.

Check assays of the ethylene dibromide concentration inside a fumigation chamber used for fruit fly destruction were carried out to test the efficiency of the chamber by the procedures laid down by the appropriate authorities.

Sixteen samples were received under the classification of explosives.

These included 4 samples of imported commercial explosives which required lengthy and time-consuming analytical work to determine their composition as each sample contained varying proportions of up to 12 different components, inclusive of "inert" material.

Two samples of fireworks alleged to be superior for pyrotechnic displays were examined to detect anything in their composition which would account for this effect.

Nine samples of imported fireworks which "exploded or strongly deflagrated" were analysed in detail to determine if any components, or mixture of components, were hazardous for ordinary use.

Two imported novelties of a type no doubt intended for "practical jokes" were also examined to determine not only the composition of the various parts, but the way these produced a "golf ball" which would burst into smoke when struck.

Two investigations were carried out during the year by the Department of Agriculture to check the extent and effectiveness of aerial spraying, and of ground spraying with a "mister" fitted with different types of nozzles. The spray, containing a dye, was deposited on test plates placed on the ground at pre-arranged distances. 186 test plates were analysed for dye deposited on the surface and the application of the spray in terms of gallons per acre calculated.

Fifty-three samples of toxic plants were received for analysis to determine the nature and amount of the injurious material, which was suspected of being fluoroacetate.

Miscellaneous samples received and examined during the year included a fuel oil for fluorine content, ammonium nitrate for traces of organic matter, a carcase-branding ink for dyes and other chemicals, an unsatisfactory paint undercoat for identification of vehicle, vermin poisons for assay, suspected ambergris for identification, a proprietary toilet cleaner, horticultural spraying oils for check against overseas standards, leathers for check against Government specifications, sheep's wool for identification of branding material, fabrics for identification of fibres, and compressed air for examination to specifications recommended for underwater use.

The normal enquiries 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.

FUEL TECHNOLOGY DIVISION.

Registrations of investigations and samples allocated to Fuel Technology Division during the year 1965 were 137, Table 30. The most noteworthy is registration 11,926 "Investigation of the mechanism of reaction of solid carbon with metallic oxides in connection with the direct reduction of ores with coal". This registration relates to a research grant of $10,000 per annum planned for two years and extending, if successful, to $20,000 per annum. The grant is from the National Coal Research Advisory Committee on which the Divisional Chief is State representative.

In contrast registration 11746, for the sub-sieve size analysis of a sample of chocolate powder claimed the modest fee of $3. It too has national significance as our work on sub-sieve size analysis has aroused the interest of the Australian Standards Association through whose agency our results and some samples of a standard finely ground silica sand were distributed to interested laboratories. One C.S.I.R.O. Laboratory has returned to us their size analysis of this silica sand and it confirms ours which was published as Table 17 of the 1964 Annual Report.

The Chief of the Division acts on the Air Pollution Control Council as Mines Department representative appointed by the Hon. Minister. Mr. L. J. Brennan has been elected by the Air Pollution Control Council to its Scientific Advisory Committee as a fuel technologist. The position is a most important one in the hierarchy of air pollution control established by the Clean Air Act.

The year has been mainly one of rounding off and completion of work commenced in past years. Researches on thermal conductivity of insulating materials and on lightweight aggregates have been completed and prepared for publication. Work on dust arrestment devices has explored this field on a number of industrial dusts up to transport speeds of 50 feet per second.

Table 30.

FUEL TECHNOLOGY DIVISION.

—	Departmental	Hospitals	Metropolitan Water Supply	Mines Department	Public		Public Health Department	Public Works Department	State Housing Commission	Total
					Free	Pay				
Atmospheric pollution	79	1	6	....	....	2	1	....	....	89
Building materials	2	....	....	3	6	3	....	....	....	14
Coal and coal products	6	....	....	....	1	7	....	....	....	14
Fuel	....	....	....	....	....	3	....	....	....	3
Miscellaneous	1	....	....	....	1	11	....	3	1	17
Total	88	1	6	3	8	26	1	3	1	137

The success of work undertaken in 1964 has also become evident during the past year. A brickworks has adopted improvements suggested and discussed in the 1964 Annual Report and has improved the standard of their output in consequence. A lucerne grower is operating successfully and profitably a drier which we helped him to design and we are hopeful that he will yet further improve the drier in detail to increase output and reduce fuel and operating costs. Reports indicate that offence by malodour from the Subiaco Sewage Treatment Works has decreased. Our feeling is that more could be done in this matter just as more could be done to improve lucerne drying. Operators of plant frequently tend to stop short of perfection where the day-to-day needs of operation claim priority in their work and on their time, but in some instances cost is a governing factor.

On the other hand the philosophy of research is so much one of attaining perfection that improvements which are stopped at the stage of reasonable satisfaction to an engineer or operator are, at times, frustrating to the research worker. This does not make for continuity of work in any application.

The year has also been broken by five visits of the Divisional Chief to meetings of the National Coal Research Advisory Committee in Melbourne, Sydney or Canberra. One of these visits combined fortunately with a meeting of Engineers in Sydney at which the Divisional Chief presented a paper detailing the chemical engineering achievements of our Laboratories. The paper opened the technical session of the meeting.

Coal Survey.

Coal survey samples analysed during the year are set out in Tables 31, 32.

Table 31.

Analyses of Miscellaneous Coal Samples.

Origin	Collie (drilling chips)	Derby (drilling core)	Fitz-gerald River (a) (specimen lump)	Alex-andra Bridge (drilling core)
Proximate analysis—	per cent	per cent	per cent	per cent
Moisture (b)	20·0	20·0	1·4	20·0
Ash	12·3	16·0	21·4	8·6
Volatile matter	26·9	27·4	33·7	27·0
Fixed carbon	40·8	36·6	43·5	44·4
	100·0	100·0	100·0	100·0
Calorific value—	Btu per lb.	Btu per lb.	Btu per lb.	Btu per lb.
Moisture basis as above	8620	8780	11360	9050
Dry, ash-free basis	12730	13720	14710	12670

(*a*) This sample was received as a single small lump of coal and may be a "rogue" sample in that it may have originated far from the area in which it was found. In analysis and properties it is different from known West Australian coals, particularly those from this area.

(*b*) Coal samples recovered from drilling are assessed on the arbitrary basis of a moisture content of twenty per cent. The true moisture content of the coal in the seam is upset by the drilling conditions.

Table 32.

Average Analyses of Coal Samples from the Working Seams of Mines at Collie.

Seam	Hebe	Centaur	Wyvern
Location	Open cut	New development	Western No. 2
Proximate analysis—	per cent	per cent	per cent
Moisture	22·9	20·2	25·5
Ash	2·0	3·4	2·9
Volatile matter	32·2	31·0	26·4
Fixed carbon	42·9	45·4	45·2
	100·0	100·0	100·0
Calorific value—	Btu per lb.	Btu per lb.	Btu per lb.
As mined	9610	9810	9170
Dry, ash-free	12800	12840	12810

Fuel Technology Work.

Advice given during the year to the operator of a brickworks tunnel kiln was to increase the dry unfired strength of one type of brick by use of some stronger clay in it since it was at about the 600°C heating-up stage that spoiling cracks developed. This advice has been followed and spoiled bricks are now a rarity on the works. Somewhat parallel advice was given with respect to the first stage drying of a second type of brick and the quality of the output of this kiln has similarly improved.

The lucerne drier referred to earlier was one on which advice was given in 1964. It has operated successfully for twelve months. It dries summer grown lucerne of inlet moisture content 43.5 per cent to give a product apparently bone dry. The exit gases were of low relative humidity, one measurement showed less than 10 per cent R.H. These figures show that the drier is working either with too much fuel or too small a load and corresponding improvements in performance could be secured. A fault found in its design was caused by the use of a large axial-flow, ex-mine ventilating fan for a prime mover. These fans tend to circulate back into the down stream dead space zone in line with the boss of the fan. On the other hand the high velocity air outside in line with the blades, sets up a suction round the periphery. This sucks air down through the drier instead of blowing it upwards. As a consequence the drier appears to develop zones of excessive heat and of excessively high air velocity. This may cause stripping and loss of leaf from the lucerne. Some signs of this can be seen such as ash in the drier bottom and pieces of leaf recirculated to the burner.

The drier should properly be fitted with a large diameter centrifugal vane type fan. This is not possible. The present axial fan's performance has to be improved. This can be done by fitting to it a tail faring to the boss to fill the dead centre zone and prevent recirculation. Axial flow straighteners should also stop the whirl of the air and direct it down the drier tunnel with a fairly even cross sectional flow.

The wood fired boilers at a hospital were tested in comparison with an oil fired boiler. The issue was the relative prices of wood and oil fuels weighted for their efficiencies in steam raising. The two types of boiler were found to be operating at normal expected efficiencies, the wood fired boiler 53 per cent and oil fired better than 70 per cent on intermittent load. It was found that on the basis of these efficiencies the tendered oil price had been quoted below the comparative wood price. There seems a general trend towards this policy in the Metropolitan Area. Thus oil is steadily supplanting wood fuel at many institutions where operation of solid fuel boilers on indigenous fuel would otherwise continue.

Fuels from S.E. Asia.—A sample of charcoal made from Malayan rubber-tree wood by the Charcoal Iron and Steel Industry works at Wundowie was submitted for analysis and comparison with charcoals made from jarrah and wandoo. The outstanding feature of the charcoal was the ease with which it could be lit and caused to smoulder. This would make it a most useful charcoal for domestic use. Our West Australian jarrah charcoal is hard to light and does not smoulder readily. Wandoo is rather better than jarrah and so too is karri charcoal. Amongst indigenous woods only banksia charcoal approaches this rubber-tree wood charcoal as an easily lit and easy burning fuel for use in the charcoal pots on which so much cooking is done in S.E. Asian countries.

Charcoal analyses are set out below in Table 33.

Table 33.

Description	Jarrah Charcoal	Wandoo Charcoal	Rubber Wood Charcoal	Rubber Bark Charcoal
Lab. No.	5615	5616	5617	5618
Proximate analysis—	per cent	per cent	per cent	per cent
Moisture	6·7 (a)	6·0 (a)	6·0 (a)	3·8 (b)
Ash	0·2	0·7	2·8	5·2
Volatile matter	23·4	21·3	18·2	24·0 (c)
Fixed carbon	69·7	72·0	73·0	67·0
Ultimate analysis—				
As analysed basis—				
Carbon	77·1	78·5	78·3	....
Hydrogen....	3·1	3·2	3·6	....
Sulphur	0·03	0·03	0·06	....
Dry, ash-free basis—				
Carbon	82·8	84·1	85·9	....
Hydrogen....	3·3	3·4	3·9	....
Calorific value—	Btu per lb.	Btu per lb.	Btu per lb.	Btu per lb.
As analysed basis	12,550	12,900	13,120	....
Dry, ash-free basis	13,480	13,830	14,390	....
True specific gravity of dry charcoal	1·28	1·27	1·29	....

(*a*) These moistures were determined as 320° C. because of the known absorptive powers of charcoal.

(*b*) This moisture was determined at 110° C.; the true free moisture content of the sample as analysed is probably close to 6 per cent.

(*c*) This volatile matter content includes that absorbed moisture which the charcoal loses only above 110° C.; the volatile matter, excluding this extra absorbed moisture, is probably close to 22 per cent.

A well ignited piece of rubber wood charcoal will continue to smoulder for about an hour in a gentle current of air.

Samples of Tenera fibre and palm nut shells were submitted for analysis and opinion on suitability for a boiler fuel. The moisture contents of the samples were low so that the calorific value at 8,000 Btu per lb. was high for a cellulosic material. The ash content was 2-5 per cent and it contained about 10 per cent of potash, K_2O, in the ash, Table 34.

Table 34

Marks	Tenera Fibre	Tenera Palm Nut Shells
Lab. No.	11065	11066
Analysis	per cent	
Moisture	9.0	10.0
Ash	4.9	2.1
Residual oils soluble in ether	4.8	not required
Potash in ash, K_2O	11.4	8.8
Calorific value	Btu per lb.	
As received basis	7860	8110
Dry, ash-free basis	9130	9230

The valuable results of these two examinations suggest that more help could be given to South-East Asian countries in advising them on the use of fuels which may at the present time be wasted.

Drying of Ilmenite Beach Sands

The flash drier designed by us for beach sand drying at Capel some years ago was inspected during the year. The plant operates satisfactorily at its designed hourly capacity of 15 tons of sand of 8 per cent moisture content. Attempts to increase the throughput result in some degree of failure to entrain.

The following suggestions were made for increasing throughput while maintaining full entrainment—

(1) Cooling the tail end gas at the inlet to the exhaust fan, if necessary by injection of water as a mist, would increase the mass of gas passing through the drier and therefore increase the velocity, mass and entrainment capacity of the hot transport gas.

(2) Raising the feed point so that the height of the teeter zone below the feed point would be increased. Alternatively improved formation of the venturi throat design below the feed point would increase velocity in the present teeter zone and improve pickup.

Dissatisfaction has been expressed over the way the flash dried sand behaves in electrostatic separation. This has been blamed on—

(a) residual moisture content

(b) fine dust content which cakes on the rolls of separators

(c) absorbed sulphuric acid.

Moisture retainable below 100°C. can be removed by fluidising the dried output product from the plant by passage over an air slide or through a small fluid bed. This also removes dust below 50 micron in size which appears to be fine dried clay caught by the high efficiency cyclone of the plant.

Sulphuric acid is not present in the dried product but over a limited temperature range lying between 400°C. and 500°C. sulphur dioxide is evolved in trace amounts from the beach sand even before it has passed through the drier. This suggests that these beach sands contain a trace amount of a sulphate, possibly iron sulphate, but it should not interfere with electrostatic separation.

The moisture retained in the Capel beach sand was examined in the laboratory. The results are set out in Table 35 which shows that the porous minerals ilmenite and leucoxene retain about one per cent. of water above 100°C.; the non-porous monazite, zircon and quartz retain no significant amount of water above 100°C. since moisture can only be held on outside surfaces. Operators who wish to relate moisture content of beach sands to electrostatic separation behaviour should therefore define both the mineral constituent and its temperature of drying.

Table 35.

Moisture Contents of Minerals in Beach Sands.

Mineral Constituent	Moisture in temperature range			
	Up to 120° C.	120–250° C.	250–550° C.	Total
	per cent	per cent	per cent	per cent
Ilmenite	0·3	0·4	0·8	1·5
Leucoxene	1·0	0·5	0·5	2·0
Tailings (mainly quartz)	0·3	0·2	n.d.	0·5
Monazite	0·1	None	n.d.	0·1
Zircon	0·05	None	n.d.	0·05
Quartz	0·05	0·04	n.d.	0·09

n.d. = not determined.

Moisture content of the various constituents is of importance in the subsequent electrostatic separations which they undergo. Our recommendation was that residual moisture content should be related to behaviour in electrostatic separation before final drying conditions were specified.

It was however suggested that residual moisture could be reduced and fine clay dust blown out of the sand leaving the drier by passing it over an air slide conveyor or through a small fluid bed so that dust and removable moisture could be eliminated from the hot, nominally dry sand.

Air Pollution

Dust:—Dust deposition has been measured throughout the year at five sampling points in the Metropolitan Area. Two are in industrial areas, one is close to an ocean beach and two are inland in suburban residential areas. The results for the year are set out in Table 36. The only comment to be made on them is that they are mainly surface sand which rises to a maximum figure in the East Perth location which is alongside a busy road.

Table 36

Dust Deposition 1965

Metropolitan Area

Test Position	Rate of deposition tons per square mile per year					
	Summer			Winter		
	Max.	Av.	Min.	Max.	Av.	Min.
Industrial						
East Perth	450	350	210	400	270	180
Rivervale	250	140	80	160	90	20
Residential						
Redcliffe	140	80	50	80	40	15
Wembley	170(a)	70	30	40	30	20
Swanbourne	100	60	20	60	40	10

(a) This figure was obtained when road making and house building operations were being carried out close to the gauge position. The next highest deposition rate was 80 tons per square mile per year.

A successful dust arrestment plant was designed for a hospital incinerator. It consists of an exhaust fan which gives a steady draught and air flow through the incinerator. A cyclone on the outlet of the fan catches the dust. The fan is operated over the short periods of firing rubbish into the incinerator and is shut off while ash is left to smoulder. This avoids the rush of air, hot gas, smoke and char which occurs under free draught when material is fired.

Investigation of the performance of dust arrestment devices continues. Twenty-five runs have been made using a high capacity cyclone and six runs have been made using an inertial separator. Materials used experimentally have comprised sawdust, charred sawdust smuts, sander dust, silica flour, gypsum plaster and gypsum. Only sawdust and gypsum were used to test the performance of the inertial separator as this device is suited for the arrestment of coarse materials only. Performance efficiencies are set out in Table 37.

Table 37

Substance	Transport Velocity fps.	Per cent retained by high capacity cyclone
Sawdust smuts	40	85
	45	62
	50	72
Sander dust	40	84
	45	85
	50	81
Silica flour	40	74
	45	86
	50	84
Plaster of Paris	40	83
	45	77
	50	88
Gypsum	40	95
	45	95
	50	94
Silica sand	40	89
	45	92
	50	90
		Inertial Separator
Sawdust	40	71
	50	60
	60	48
Gypsum	40	85
	50	81
	60	73

The work has now reached the interim report stage for transport velocities of up to 50-60 fps. This is the limit set by the present fan on the installation. Continuation of the work to higher velocities depends on availability of a higher duty fan.

Odour:— Contact with the Subiaco sewage plant has only been slight during the year. The burner which we designed last year to destroy odour from the sludge settlement tanks operates so successfully that burners were considered for odour destruction at other places on the sewage system where nuisance occurs. In a way this is gratifying. Imitation and repetition constitute high praise. Our preference for odour destruction would have been by absorption using active iron oxide and wood charcoal. This combination seemed good in the laboratory but it has not been tried on the plant.

Attention has also been given to sweetening of sources of less intense odour on the sewage plant especially to the aeration tanks. Large volumes of air are blown through the sewage in these tanks and emerge to spread a flat, amine type of odour in the neighbourhood.

Reports from the United States of sewage scented with the odour of pleasant smelling effluent from a chocolate factory suggested vanillin as an odorant. Small quantities of commercial odorants, citronella, vanillin, coumarin, pine oils and tonarome were tested in the laboratory. Coumarin and vanillin had the lowest threshold odour values. From the results it was calculated that about a dollar a day spent on any one of these odorants introduced into the sewage aeration air could scent the works pleasantly.

Sulphur dioxide:— A minerals processing plant was asked last year to raise its boiler chimneys to comply with accepted industrial practice relating chimney height to sulphur dioxide emission. It has complied with this suggestion. The plant is a minerals processing plant and comes under the Mines Act, not the Factory Act.

An attempt was made to measure the sulphur dioxide content of the chimney gases two hundred yards down wind and on a level with the chimney tops of a boiler installation. Less than 0.1 p.p.m. SO_2 was found although a faint odour of burnt fuel oil was borne on the wind to the test points. There was a brisk wind with an apparently high lapse rate giving rapid dissipation of any pollutant. Such conditions prevail in the State and are a major safeguard against local pollution from chimneys. There are however other weather conditions which may spread pollution at ground level from major sources of sulphur dioxide emission such as large power stations using fuel oil of high sulphur content. A possible one hundred tons a day of sulphur oxides has been calculated for one new projected power station if it uses fuel oil. Some ground level pollution could be expected from such a station unless it has chimneys of adequate height. High level sulphur trioxide droplet haze in its chimney plume is a second possibility in bright, sunny weather, when conditions suit photochemical oxidation.

Light Weight Aggregates.

The pyroplastic behaviour and the gas evolution at bloating temperature have been studied for a number of Australian clays and shales. A steady evolution of gas consisting principally of carbon monoxide commences below 1,000°C. The gas evolution continues into the fluxing or pyroplastic temperature range and so causes bloating. Varying quantities of hydrogen accompany the carbon monoxide and this can come from the reaction of water of constitution with the carbon in the shales and clays. Less than 1.0 per cent of carbon is required to produce large quantities of gas from shales and clays and less than 0.1 per cent will give more than sufficient gas to cause bloating. An alluvial silt examined departs from the general predominance of carbon monoxide in the gases evolved from it and shows a predominance of carbon dioxide and this may be related to the presence of free limonite in the silt. In support of the essential role of carbon in bloating it is always found that bloating can be prevented by removal of carbon by burning in air or oxygen at 750°C.

On the other hand acid treatment to remove carbonates does not prevent bloating. Organic or graphitic carbon and not carbonate carbon provides in reaction with metallic oxides and possibly water of constitution the essential agent for bloating.

Metal Oxides Reduction.

The $10,000 grant from the National Coal Research Advisory Committee referred to at the beginning of this report relates to an investigation of the reaction of solid carbon with metallic oxides. The work can eventually extend to cover the direct reduction of West Australian iron ores to yield sponge iron. Sponge iron and partly reduced iron ores attract interest in relation to newer techniques in iron and steel metallurgy.

At present the investigation is restricted to registration 11926/65 "Investigations of the mechanism of reaction of solid carbon with metallic oxides in connection with the direct reduction of ores with coal". Work on it is at present limited to characterisation of reaction with chars prepared from Collie coal at various temperatures and comparative work is being done using other forms of carbon.

The object of the work is to elucidate the mechanism of reaction between solid carbon and metal oxides, particularly iron oxides either as hematite or other iron ore and, as well, iron oxide combined in ilmenite. Work is at present confined to ilmenite beneficiation involving the reduction of the iron oxide in the ilmenite.

Work already published by R. G. Becher et al of our Laboratories on "A New Process for Upgrading Ilmenitic Mineral Sands" (Aust. Inst. Min. & Met. Proc. 1965, 214, p.21) suggests that the degree of reduction is dependent on the history of the char used in reduction. It is the immediate object of research to investigate the rate, degree and mechanism of reduction of ilmenite by various coal chars and other forms of carbon.

The apparatus set up for this purpose consists of electric furnaces in which silica reaction tubes containing the reactants can be heated to temperatures up to 1200°C. Gaseous products are collected in an evacuated train and thence removed for analysis. Iron is determined in residual samples avoiding so far as possible contact with air.

The work has been confined to the reduction of ilmenite by char made from Collie Coal. Seventeen runs have been completed. The highest reduction of the iron oxide present in the ilmenite has been 97.3 per cent the lowest 78.6 per cent The gases evolved in the reduction have been collected and analysed. They contain mainly carbon monoxide and hydrogen. Hydrogen persists above 1100°C.

It is evident that the interaction between carbon and a reducible oxide can be visualised as taking place through the intermediary of either water vapour, oxygen or carbon dioxide which bring the carbon into reaction as carbon monoxide originating from the char i.e. carbon, to carbon dioxide at the iron surface followed by subsequent reduction of the carbon dioxide back to monoxide at the char i.e. carbon surface. Hydrogen will not be self renewing unless it is either available as volatile matter in the carbon or is supplied by steam or hydrocarbons.

This outlines the field of research which can be examined in the future in detail. It is related to similar iron oxide-carbon reaction occurring in the bloating of carbonaceous shales. Here, too, hydrogen persists to the bloating temperature of 1100°C.

INDUSTRIAL CHEMISTRY DIVISION.

Staff.

At 31st December, 1965 there were five chemists (including the Divisional Chief), one laboratory technician and two laboratory assistants on the staff. One of the chemists had been temporarily seconded to the Agriculture and Water Supply Division.

From February to November Mr. Reid lectured at Carlisle Technical School on Reinforced Plastics.

Classification of Work.

The work of the Division may be conveniently classified under the headings:—

(1) Building Materials, including paints and plastics.
(2) Assistance to Industry.
(3) Investigational Work.
(4) Consultative Practice (Advisory Service).
(5) Miscellaneous.

There were 82 registrations of samples and investigations allocated to this Division during the year, one more than last year. Of these a high proportion were building materials, including paints, and plastics used in building. The origin and types of samples are indicated in Table 38.

Table 38.

INDUSTRIAL CHEMISTRY DIVISION.

—	Agriculture Department	Forests Department	Main Roads Department	Mines Department	Public Health Department	Public Pay	Public Works Department	State Housing Commission	Total
Building materials	....	1	....	16	....	4	29	13	63
Plastics	1	1	....	....	1	....	1	....	4
Miscellaneous	3	....	3	3	....	5	1	....	15
Total	4	2	3	19	1	9	31	13	82

Building Materials.

Staining of fibrous plaster.—A total of 15 samples were examined in the investigation of 3 cases of staining of fibrous plaster. Lengthy investigations into causes of the stains showed that in most cases the stains were mainly caused by water-soluble organic material originating in the fibre used to reinforce the plasterboard, but green timber used as ceiling joists might also be responsible in some cases. The only satisfactory method of treatment seems to be to cover the stains with a quality paint of good hiding power. Although the stains could to a large extent be avoided by pre-washing of the coconut and sisal fibre, it appears more economical to accept the occurrence of the stains and paint over them.

Paints and paint failures.—Three samples of a particular brand of paint were examined for the Government Tender Board after complaints by painters using them. It was found that the high viscosity of these paints was responsible for poor brushability, and that dilution of the paints with thinners, although reducing viscosity and improving brushability, reduced the hiding power to an unsatisfactory level. Examination of two laboratory stock samples of the same brand and type of paint confirmed that the fault was not one of that particular batch, but appeared to be of the brand in general. Two laboratory stock samples of a different brand of paint showed on examination that although the pigment, vehicle and volatiles contents were of the same order, the physical properties, (particularly viscosity) were very different.

Accelerated weathering tests were carried out on eight samples of paints using test panels of timber and galvanised iron coated with the paints, the object being to determine the comparative lives of the paints. Accelerated weathering was carried out in the ultra violet light exposure weatherometer which had been modified to incorporate temperature and humidity changes. The modifications comprised water sprays and infra-red heat source. Intermittent operation was obtained with a system of solenoid switches and programme controller made in the laboratory.

At the end of the year only slight variations in the durability of the finishes on both substrates were apparent.

Investigation of a paint failure on a wooden post showed that the failure was due to faulty technique, in that firstly, the undercoat had not dried completely before application of the top-coat, and secondly, the article which was painted at a depot and then transferred to the site had suffered mechanical damage in transit.

Failure of a zinc rich paint on steel roof trusses was found to be due to poor surface preparation, particularly inadequate removal of mill scale. Examination of peeled paint flakes showed that the paint film was in good condition, but had been lifted off by expansion of the oxidising mill scale on the steelwork.

Miscellaneous building materials.—Three samples of insect screen wire were examined for their relative merits and demerits. All three were tested under accelerated weathering conditions to simulate a marine environment. Special apparatus was improvised for test purposes. The conclusion was, as expected, that stainless steel wire was more suitable than fibreglass, which was slightly more suitable than aluminium for the specified environment.

Six samples (three grades each of two brands) of building insulating paper were compared. These were found to vary considerably in both nature and quantity of their components. The significant difference between the two brands was that one brand contained a mixture of glass fibre and sisal as reinforcement, whereas the other brand contained only glass fibres.

Two samples of different brands of ceramic floor tiles were tested for water permeability. No significant difference was found between the two.

A sample of a concrete admixture of the calcium lignosulphonate type was analysed for compliance with specification, and a sample of set concrete was examined to ascertain if an additive had been used, and to what extent.

A flexible foam plastic, coated with a protective skin of nitrile vinyl rubber was examined for resistance to solvents and chemicals. The plastic, of annular tube shape, was intended for use as a thermal insulator for piping.

Assistance to Industry.

An investigation on behalf of a local wool scouring firm was conducted into the solvent extraction of wool grease from dried wool scour effluent. The large scale equipment in the Unit Process Plant was used, and a quantity of wool grease prepared for market assessment. The firm was advised of possible methods of applying solvent extraction to their by-product.

A client wishing to manufacture copper sulphate for agricultural purposes was advised of the technical details of a suitable process, using scrap copper, sulphuric acid, and supplying additional oxygen by passing air through the hot mixture. The client was also advised of the type of plant required, size of vessels and suitable materials of construction.

Advice was given to a client wishing to utilise as a fertiliser, flue dust, a cement manufacture by-product high in potassium sulphate. He was advised that a saleable product could be made by pelletising the material, and this process, and the necessary equipment were described. Subsequently we were informed that the method was successful and that commercial production had begun.

To assist a local firm in the design of a pilot plant, experiments were conducted, using improvised equipment, to determine the minimum velocity and duct size at which a specified quantity of their product, a fibrous material could be conveyed by pneumatic means.

A local firm rearing table poultry was experiencing the problem of low weight gain in birds fed on certain types of poultry foods. To enable them to ascertain whether the deleterious factor was in the fat or non-fat fraction, the fats from satisfactory and unsatisfactory feeding stuffs were extracted and interchanged. These substituted products were then used in feeding trials.

Investigational.

Measurement and evaluation of "Slip".—The design and construction of the portable slip testing apparatus mentioned in the 1964 Annual Report has now been completed, and data are being evaluated with those obtained from the standard laboratory apparatus.

The portable slip testing instrument measures the acceleration of a shoe sliding over a surface of length 75 cm under a horizontal force. The average acceleration figures thus obtained are used to grade surfaces, or surface pairs, as regards their relative slipperiness—not to assess a non-slip value for safe walking.

The non-slip value of surfaces for safe walking will be assessed on the highest acceleration obtained over an interval in a traverse not less than **55 cm (one interval = 5.5 cm)**. It is proposed to standardise the method of testing for slip with our apparatus in order to arrive at a specification for safe walkways.

Painting of cold-galvanised metal.—A lengthy investigation into the causes of, and remedies for, the failure of oil based paints when used over the zinc dust—sodium silicate type of metal protection was concluded. The failure was attributed to efflorescence of sodium salts, particularly carbonate and sulphate; and the solution was to allow the surface to weather, and water wash, preferably by total immersion, to remove all soluble salts. As an alternative it was observed that some water based paints could be applied directly to the newly zinc treated metal. A report covering the complete investigation is in draft.

Painting of Karri Timber.—Conferences with other interested parties, including the Forests Department, State Housing Commission and Timber Development Association, were held to decide the future of the project.

It was decided during the year that larger test panels for paint exposure would give more reliable results. This necessitated changing from exposure racks to test fences. Sites have been prepared, and arrangements have been made for the erection of the first test fence at Welshpool.

Preparation of lithium salts.—Although encouraging results were obtained in the extraction of lithium salts from lepidolite by low temperature roasting with sulphuric acid and acid sulphates, work on lithium recovery from this source was discontinued because known reserves of lepidolite in this State are said to be low.

Investigations were continued on the extraction of lithium salts from petalite and it was confirmed that methods used for lepidolite were not applicable to petalite.

Base exchange techniques by fusion of various particle size fractions of petalite with sodium chloride above the melting point of sodium chloride were tried, and it was found with the calcined and uncalcined petalite, that although there was a slight increase in percentage recovery of lithium with increasng fineness, the best recovery figures obtained (9.6 per cent) were far too low to be of economic value. This technique was therefore abandoned as a possible commercial method.

As reported in the 1964 Annual Report, petalite, after calcination to β-spodumene and silica, lends itself readily to chlorination by gaseous chlorine. Further experiments were carried out with the object of (a) lowering the temperature at which chlorination takes place, and (b) seeking to eliminate the calcination step. An electrically heated tube furnace was constructed, and later modified for use as a laboratory size fluid-bed reactor. The results of batch experiments in this reactor showed that at 800° C, 42 per cent recovery of lithium was possible from calcined ore, but for uncalcined ore the same conditions gave 23 per cent recovery. It is therefore necessary to calcine the ore, both to improve recovery figures, and reduce grinding costs. Grinding costs of uncalcined petalite would be excessive due to high power consumption and heavy wear on equipment.

It is believed that during the conversion process atmospheric moisture reacts with nascent chlorine to form gaseous hydrogen chloride. By drying the ingoing air this may be avoided, with a subsequent improvement in recovery figures. At least 90 per cent recovery would be necessary to justify placing the process on a commercial basis. It is proposed to run a trial, drying the ingoing air by passing it through molecular sieves of 5Å space. This method has been chosen because it can lower the moisture content of the air to 15 p.p.m., and is the most suitable method of drying air on a large scale.

Advisory Service.

As is usual the Division had a large number of personal and telephone calls requesting information and advice on a wide variety of subjects. The great majority of these were of a confidential nature. Many could be answered forthwith, but a few required investigation and literature searches.

There were frequent requests for formulations, trade names, suppliers, agents and the like; a few involved chemical engineering problems.

Building materials formed the largest single item in the various classes of enquiry, but plastics and paints came a close second and third.

Instead of acquiring voluminous data on the many topics raised by clients we have adopted a system whereby, if the answer required is not on file, the enquirer can be directed to the particular expert or specialist in the particular field. This system has worked extremely well, thanks to the co-operation of Government Departments, libraries, manufacturers, suppliers and professional men. The frank interchange of technical matter and professional opinions has been most encouraging. As an instance a local firm found themselves in need of 1½ cwt. of a raw material for a rush order which had to be made and shipped out within 36 hours. The appropriate expert was contacted and within an hour the material was on its way to the factory.

Help and technical advice have also been forthcoming from overseas visitors from the United Kingdom, United States of America, Germany and France and the consulates of various countries have also been very helpful.

Although big industry with its own staff of professional men is taking over more and more in Western Australia, there are still a very large number of smaller operators, functioning profitably, who continue to rely on the Division and its officers for advice and technical information.

Miscellaneous.

Two samples of sandalwood were examined for steam-volatile and solvent-soluble oil. This work was undertaken because of discrepancies between analytical figures and commercial oil yields.

Three samples of lubricating oil by-products were emulsified prior to assessing their suitability as aggregate binders for road repair work. It was found afterwards that the emulsions were too viscous to permit sufficient penetration, and less viscous emulsions were prepared for penetration tests with two of the oils by lowering the oil/water ratio. The most viscous oil could not be satisfactorily emulsified at a low oil/water ratio.

To assist the Entomolgy Branch of the Agriculture Department in fruit fly trials, a self-emulsifying concentrate of a new organic phosphate insecticide was formulated.

An investigation into crystal penetration and water vapour permeability of a plastic used for coating poisoned oats, showed that the fault lay in the coating technique, not in the type or thickness of the coating material.

MINERALOGY, MINERAL TECHNOLOGY AND GEO-CHEMISTRY DIVISION.

General.

The number of samples examined during 1965 was more than double that of 1964. This increase is due largely to a programme of research aid for the gold mining industry. Independent of that programme however, the number of samples examined was the highest yearly total handled by the Division.

The main sources of samples were—

General Public (free)	3,210
General Public (pay)	741
Geological Survey Branch	243
Departmental	204
State Batteries	193
United States Navy	118

In addition to the Mines Department and its Branches fifteen Government departments or instrumentalities including one Commonwealth department, submitted samples for examination.

Table 39.

MINERAL DIVISION.

	Public		Departmental	Metropolitan Water Supply	Mines Department	Public Works Department	Public Health Department	Other Government Departments	United States Navy	Total
	Pay	Free								
Burnt lime	50	....	1	....	3	....	....	....	....	54
Clays	1	33	....	....	7	3	....	1	....	45
Concrete (*a*)	37	....	2	16	....	5	....	1	8	69
Corrosion	3	....	....	2	1	....	....	....	110	116
Dusts	10	....	67	....	....	....	27	2	....	106
Mineral identifications	43	439	106	....	16	....	....	2	....	606
Minerals and ores—										
Arsenic	....	2,077	....	....	....	....	....	....	....	2,077
Bauxite	3	11	....	....	10	....	....	....	....	24
Bentonite	51	16	1	....	....	....	....	....	....	68
Beryl	5	7	....	....	....	....	....	....	....	12
Copper	67	113	2	....	9	....	....	1	....	192
Gold ores	66	153	....	....	29	....	....	....	....	248
Gold tails	....	....	....	....	118	....	....	....	....	118
Gold umpires	....	....	....	....	12	....	....	....	....	12
Gypsum	5	7	....	....	1	....	....	....	....	13
Heavy sands	9	74	....	....	18	....	....	....	....	101
Iron	99	107	....	....	26	....	....	....	....	232
Lead	13	17	....	....	66	....	....	5	....	101
Lithium	5	7	8	....	3	....	....	....	....	23
Manganese	7	10	1	....	....	....	....	....	....	18
Phosphate	12	4	3	....	31	....	....	....	....	50
Tantalite	27	15	....	....	....	....	....	....	....	42
Tin	146	22	1	....	4	....	....	4	....	177
Titanium	8	2	....	....	1	....	....	....	....	11
Tungsten	8	12	....	....	1	....	....	....	....	21
Vanadium	1	15	....	....	....	....	....	....	....	16
Others	40	65	9	....	87	....	....	3	....	204
Miscellaneous investigations	25	1	....	2	2	18	3	15	....	66
Complete analyses	....	3	3	....	10	....	....	....	....	16
Total	741	3,210	204	20	455	26	30	34	118	4,838

(*a*) Includes cement and aggregates.

A general trend which has developed over the last 2 or 3 years has been a change in the source of samples from the general public. Whereas in the past most samples were from individual prospectors and mineral dealers, the trend is towards more samples from organised mining and prospecting groups which have financial backing and therefore greater prospecting potential.

It is noticeable that when these big groups establish their own laboratories, the investigations they submit to these laboratories are largely for checking and standardisation.

In 1965 samples were submitted by 11 well established mining and mineral dealing firms and 19 organisations active in a prospecting role. Systematic prospecting schemes by individuals have also been supported.

Staff.—To assist in a program of geochemical testing of areas of interest in Kalgoorlie gold field, Mr. E. Tovey was appointed temporary laboratory technician Grade 3 on the 18th January, 1965.

Mr. P. Bridge transferred from wages staff to permanent staff as Laboratory Assistant on 14th July, 1965.

Mr. F. Wood resigned from the staff on the 6th August, 1965.

On 8th November, 1965, Mr. I. Twaddle was appointed as Laboratory Technician Grade 2.

The only Long Service Leave taken from the Division was 3 months by Mr. J. Bateman.

New Equipment.—During the year the Division took delivery of a Fisher Duo-Spectranal. This is an instrument which may be used for the qualitative and semi-quantitative analysis of solutions of the sixty or more elements which can be analysed spectroscopically. To date its main uses have been for rapid qualitative work and for confirmation of analyses which have been carried out by normal wet methods. Further calibration work is needed before it can be successfully used in the semi-quantitative field.

Plans have been drawn up for the construction of an improved apparatus for the determination of total water in rocks. This apparatus, which is expected to be made locally, will enable complete removal of water from minerals in which it is retained to temperatures as high as 1250° C.

The acquisition of a Techtron Atomic Asborption Spectrophotometer by another Division has enabled more rapid determination of a number of elements while its advantages for others has yet to be proved. It has been used regularly for amounts in the order of, and less than, 1 per cent. of copper, nickel, lead and zinc. Other elements for which it has been used, include bismuth, molybdenum, calcium, magnesium, antimony, iron, tin and manganese.

The micro-reflectometer for examination of polished minerals, which was mentioned in the report for 1964 has been put in service with the arrival of imported parts. These include a standard reflecting surface for calibration, narrow band pass spectral filters, a screw micrometer eyepiece, and a rotary mica compensator.

Phase contrast accessories for the Leitz Dialux-Pol microscopes have been procured to assist in microscopic analysis of dusts.

In addition to equipment acquired, advantage has been taken of the good services of Departments of the University of W.A. to use equipment which is receiving consideration for addition to our own facilities. A single crystal X-Ray diffraction camera has been used to obtain data on new mineral species yet to be described. The Leitz Miniload microhardness tester has been used in conjunction with our own micro-reflecting apparatus. Also, unit cell calculations have been greatly facilitated by the use of the I.B.M. 1620, and P.D.P.6 computors. Considerable time has been spent in modifying and rewriting programmes for several crystal systems.

Field Excursions.—Two excursions were made during the year. Mr. Burns visited the site of a new pegmatite tin occurrence 6 miles South of Norseman, and collected specimens also from Spargoville, Londonderry and Bulong.

Late in the year, the Divisional Chief, Mr. G. H. Payne took advantage of an invitation by a mineral dealing firm to fly to the Horseshoe manganese mine at Peak Hill and also to inspect bulk ore loading arrangements at Geraldton.

Exhibitions.—Following a request by the Hon. Minister to provide an exhibit of minerals and mineral examination methods for public display, a projection microscope has been acquired which graphically presents an enlarged image of microscope slides so that properties of minerals in thin section may be discussed. Apart from satisfying public interest in minerals, this equipment has proved valuable in providing simultaneous viewing for consultation between staff members.

An exhibition was provided this year for the City Beach Kindergarten Fete. The preparation and manning of these types of display is indicative of the interest shown by the staff in their field of study.

During August the Division was host to a number of students interested in laboratory work, as part of the Department of Labour's Careers Week.

Court Appearances:— On two occasions the Divisional Chief was subpoenaed to appear in Court as an expert witness. One case related to a mining claim to a clay deposit. The second was a compensation case related to silicosis of a worker.

Laboratory Assessments:— At the request of the National Association of Testing Authorities, two members of the Division agreed to act as assessors for the re-registration of laboratories in the field of chemical testing.

In August Mr. Burns reported on the Kalgoorlie School of Mines Metallurgical Laboratory.

At the close of the year arrangements were in hand for Mr. Payne to report on the laboratory of the Charcoal Iron and Steel Industry at Wundowie.

Mineral Resources Pamphlet:— Numerous requests have been received for more up to date information than is contained in the current (1945) edition of this publication.

Approval was given in 1963 for this Pamphlet to be re-written. Officers of the Geological Survey Branch and this Division finalised the draft for the new edition in May, 1964. At the close of 1965 the first galley proofs have yet to be checked having just been received from the printer.

ORES AND MINERALS.

1. Arsenic.— Late in 1964 discussions took place with representatives of a mining concern actively carrying out research into the nature and structure of Kalgoorlie ore bodies. These discussions followed a decision of the Minister that these Laboratories should give all assistance possible to the research project, both chemical and mineralogical.

The resulting participation of this Division in the project this year has been the determination of arsenic concentration in 2,077 samples for which purpose an additional Grade 3 Technician has been added to the staff. In late 1964 check assays were done on a number of samples previously analysed in Kalgoorlie. Differences were shown between the Kalgoorlie results and those of this Division by both the Gutzeit and Molybdenum Blue methods. As a result of discussions the Molybdenum Blue method has been used for all samples assayed to date. Although considerably slower than the Gutzeit method it has been adequate to handle the number of samples received. Samples assayed to date have ranged from less than 1 to 990 parts per million (p.p.m.) Arsenic, As.

Examination of results reported early in the year, from sample sites in line across known ore bodies, has shown a positive correlation between gold assays and parts per million of arsenic. Some arsenic "peaks" have occurred without coincident gold peaks, possibly due to a halo effect around gold occurring in the third dimension.

Another group of 164 soil samples, submitted from Marvel Loch by a University Honours student, were also assayed in the p.p.m. range. It is understood that good correlation was obtained between these and known gold figures.

Some interest has been shown in arsenic in dump material from the old Wiluna mines (see spurious minerals).

2. Bauxite:— Twenty four samples of bauxitic material were examined this year largely from individual members of the public.

These samples were all below the alumina content of the areas being worked by the local alumina plant and assayed less than 20 per cent Al_2O_3. Areas represented include Walgoolan (19 miles from Merredin), Mt. Helena, Quinninup, Yornup, Jarrahdale and a site 17 miles East of Three Springs.

A sample submitted by a public analyst was examined to determine the reason for a considerable difference between assay figures for available and total alumina. This difference was attributable to the presence of considerable diaspore in the sample. Anatase was also found to be present.

From the Geological Survey Branch a suite of samples was submitted representing a bauxitic material from Montague Sound area. Three of the samples represented lateritic material high in Fe_2O_3.

A sample of bauxite composed of massive fine grained gibbsite with nodules of fibrous gibbsite, and voids lined with crystalline gibbsite, contained a little dispersed anatase, and had the following analysis—

	per cent on dry basis
SiO_2	0·86
Al_2O_3	60·7
Fe_2O_3	2·53
FeO	Not detected
MnO	0·01
H_2O+	32·3

Samples from Temporary Reserve 3500H in the Montague Sound area consisted essentially of gibbsite with varying amounts of hematite, goethite, anatase, boehmite and corundum.

The analyses of these samples is:

	per cent dry basis			
Available Al_2O_3	42.2	53.3	48.7	57.7
Total Al_2O_3	47.5	58.8	61.9	59.4
Reactive SiO_2	1.0	1.6	1.31	1.20
Total SiO_2	1.24	1.64	1.38	1.24
Fe_2O_3	15.6	4.59	4.15	3.57
TiO_2	10.2	4.99	4.09	4.32

Six samples of laterite from Beverley Springs Station in the North Kimberley Division were examined for trace metals and are reported on by the Agriculture and Water Supply Division.

3. Bentonite:— In previous reports bentonite has been discussed under the general heading of clays, although deposits at Marchagee and Cardabia have been examined for usefulness as drilling mud, fullers earth, etc. Because of the prospect of plants for pelletising iron ore being constructed in the near future attention has been given to local bentonitic clays as a pelletising medium.

Sixty eight samples have been submitted for this purpose.

As an initial sorting of possible materials, the surface absorbtion properties of the clays were tested by the methylene blue test, and a rough estimate of percentage of bentonitic material was obtained by Sadlers gelling test.

A departmental investigation was made to correlate the results of these tests on samples from known localities and the results of a test devised to measure the "green" strength of pellets prepared from these bentonites. Similar tests were conducted on the accepted "Wyoming" bentonite as a check. The correlation between the "field" tests and green pellet strength was not very marked.

While most of the samples examined came from deposits which have been worked at Marchagee and Cardabia a sample from 10 miles East of Gunyidi contained 63 per cent bentonite, and another from 10 miles South of Coorow was shown to consist of montmorillonite and sepiolite.

4. Beryl:— A steady decrease in the number of beryl samples submitted over the last three years has accompanied a decline in price of beryl. At the end of 1965 the price had fallen below £10 per unit. Five samples only of sales parcels of beryl were submitted during the year, and none at all between January and September.

An interesting specimen submitted from 1 mile South of Paynes Find was beryl with quartz and feldspar and a little phenakite (beryllium silicate) with iron oxides and mica. This is a new localty for phenakite.

A new locality for beryl is the tin bearing pegmatite on P.A. 2595, 6 miles South of Norseman. Pink beryl (morganite) was found there with albite, quartz and lepidolite.

Other occurrences represented by specimens submitted were at Tantalite Hill; Ravensthorpe area; Tambourah Hills, 15 miles West of Hillside Station; and localities 40 miles West of Cue and 14 miles South of Windimurra Station.

5. Clays:— A large increase in the number of clays examined occurred this year in addition to those submitted as suspected benonites.

When firing tests were conducted the assistance of the Fuel Technology Division was obtained to determine refractoriness under load and hence ability to withstand normal firing treatment.

Some interesting clays examined are:

From 10 miles West of Holleton.—A clay, 44 per cent clay substance, moulded easily but was short working. Burned to a friable pale pinkish buff below 1050° C. but at 1150° C. was tough, steel hard and greyish white. No collapse occurred under load.

From Dalyup River ex Geological Survey.—A clay, 46 per cent clay substance, which moulded easily but was sticky. Friable and terra cotta coloured when fired at 1050° C., was dark red but still friable and under steel hard at 1250° C.

A second sample from the same locality with 63 per cent clay substance was similar to above at 1250° C. was deep red brown, steel hard and of good shape. This clay bloated in a reducing atmosphere but would be a satisfactory brick clay with normal firing.

Also submitted by the Geological Survey from Coramup River was a clay with 38 per cent clay substance which burned through colours of cinnamon, terra cotta, brown to dark red at 1250° C., when it was still friable and under steel hard but of good shape. A second sample had only 27 per cent clay substance.

A group of three clays were submitted from 8 miles North East of Boddalin. One with 35 per cent clay substance moulded easily but was short working. Below 1150° C. it was buff coloured but very friable and under steel hard. at 1250° C. it was pinkish buff and tough but very porous. The second sample with 57 per cent clay substance was not easy to mould. A tough dense terra cotta brick was formed at 1000° C. in an oxidising atmosphere. It darkened with some distortion and cracks above this temperature and bloated in a reducing atmosphere. The third sample with 78 per cent clay substance was similar to the second, and could also make good bricks when burned in optimum conditions.

A clay from 20 miles East of Cranbrook burned to a pale cream but was friable up to 1050° C. At 1150° C. it was steel hard, tough and of good shape with incipient vitrification. A deposit from 1 mile East of the above had a salt content of 5.5 per cent and cracked when dried at 105° C.

Two pale buff clays which preliminary tests indicated may be useful brick clays came from Gunyidi P.A.1145H from 0-24′ and 24-60′.

Other kaolinitic clays were examined from Twin Peaks on Mangaroon Station, Kennedy Range and Woodie Woodie Station. From 20 miles North of Coolgardie a kaolin with quartz and illite had a strong green organic stain. An halloysite from 9 miles North of Hine's Hill contained 3.62 per cent water soluble salts.

A New South Wales company interested in the manufacture of a cement-clay submitted a clay suitable for its purpose. It had a dye absorption figure (Ashley) of 79 and a shrinkage from plastic to air dry state of 5.8 per cent. From our records, clays from 12 localities were recommended as having comparable characteristics and samples of seven of these were forwarded from the Divisional Collection.

The load bearing capacity of a number of clays was the subject of interest for other samples submitted. A brick building on a clay base had shown excessive cracking. Discussions however disclosed that the samples examined had been heated before submission thereby invalidating the conclusion which had been drawn from the examination.

Other samples from the Ravensthorpe town water supply catchment were classified by mineral content and cation exchange capacity. The nature and quantity of soluble salts present was also reported.

Related to load bearing clays was a request from an engineer for the specific gravity of a clay. It was not possible to learn the state of dryness of the clay which would give the specific gravity suitable for substitution in the engineering formula as proposed.

Another investigation which consumed a large amount of professional time concerned three metamorphosed shales from 1¾ miles East South East of Mundijong Railway Station. Legal argument turned on the definition of a mineral in a case to decide whether the holder of a mineral claim should have to pay quarrying fees to a local government authority. Advice was given on scientific definitions of several minerals and combinations of minerals.

6. Copper.—The number of samples submitted for copper assay increased by 65 per cent over that for 1964, mainly with samples from the public, both "pay" and free for prospectors.

A ready market has been maintained for oxidised copper ores assaying more than 10 per cent copper. The restriction of acceptance by fertilizer companies to ores guaranteed above 10 per cent has made supply difficult at times.

Samples from Yoothapina Station 30 miles North West of Meekatharra assayed between 12 and 25 per cent copper with up to 21 oz. per ton of silver. The copper minerals were malachite, chrysocolla, chalcocite and cuprite associated with arsenopyrite. Malachite and chrysocolla with iron oxides, quartz and clay from Arthur River 20 miles North East of Mt. Dalgety assayed from 13 to 32 per cent copper with 4 to 12 dwts of silver.

Specimens of malachite and cuprite with iron oxide and quartz from Tallering Station assayed 26 per cent copper. A brochantite specimen was received from 22 miles North West of Coolgardie.

From 2 miles North of Murchison River bridge a sample assayed 44 per cent copper as chalcocite, chalcopyrite, malachite, covellite and digenite. This was a new locality for the two last named minerals.

From South Copper Hills, 40 miles South of Marble Bar a sample of malachite and hematite with covellite, cuprite, chalcopyrite, quartz and azurite assayed 35 per cent copper and 14 oz. per ton silver.

From Ogilvie Siding 16 miles North of Northampton a specimen of cuprite and malachite with quartz, calcite and iron oxide was received.

From Mooloo Downs, chalcocite and malachite occurred with quartz and mica impregnated with malachite.

From Warburton Ranges came a sample of chalcocite, digenite, covellite, malachite and hematite assaying 71 per cent copper.

Other areas prospected, with the approximate copper values assayed, are as follows:—

> 26 miles North East of Cue, 26 per cent, 14 per cent; 6 miles West of Gifford Creek Station, 12 per cent, 20 per cent; 17 miles South East of Uaroo Station, 12 per cent; 30 miles South West of Yalgoo, 18 per cent; Old M.L.I. Day Dawn, 25 per cent; 60 miles East of Mt. Magnet on Windsor Station, 12 per cent; Jerramongup, 25 per cent; Windimurra Station near Mt. Magnet, 18 per cent; 1½ miles South West of Fields Find, 30 per cent; ¼ mile West of Paynes Crusoe, 12 per cent; Mt. Elder in East Kimberley, 17 to 31 per cent.

In connection with iron ore investigations at Mt. Gibson a large number of assays for copper were reported in the range of 0.01 to 0.20 per cent.

An interesting specimen from 30 miles South East of Roebourne consisted of a mixture of chrysocolla and natroalunite with amorphous silica. The chrysocolla content was approximately 50 per cent and natroalunite 15 per cent. The specific gravity was 0.5 and the specimen assayed 21 per cent copper.

The interest of a large mining group in a large mass, low value deposit at Arrino, lead to a number of assays in the range up to 2 per cent.

Assays in the parts per million range were done as a calibration of the methods used by a consulting geologist for geo-chemical prospecting. Very approximate correlation was found with the geochemical work.

7. Gold and silver.—The large increase in samples from companies holding mineral claims and reserves, and exploring gold prospects together with other minerals, has not been maintained this year. The number of pay samples for gold has decreased considerably below that of preceding years suggesting that mining capital may have found other fields of interest. Samples have been received from old mine dumps and others have been submitted by private analysts not equipped for fire assay.

An investigation was conducted into the reasons for poor amalgamation recovery of one ore. The gold in this sample was free and clean but extremely finely divided. No deleterious minerals were present and no obvious cause of poor recovery was noted. Further work is being done.

A number of assays for both gold and silver were made for a large prospecting firm operating a laboratory in the North. The purpose of these assays was to calibrate a wet chemical method being investigated by the firm.

Assays done free for prospectors increased in 1965.

Areas from which gold assays of greater than 1 oz. per ton were obtained, include Hatters Hill, Curtin, South of Stirlings, 15 miles North West of Meekatharra, 35 miles North East of Nullagine and Mangaroon Station. A number of these areas, when further sampled, yielded assays of less than 2 grains per ton.

For the Geological Survey Branch, assays have been made on samples from the vicinity of the Star of Mangaroon mine; G.M.L. 293 at Nullagine; Ulawarra Station and Mt. Padbury.

Samples submitted by the State Batteries Branch for check of assays at various batteries increased this year while umpire assays relating to disputes between battery and client decreased.

Approximately six oz. of silver per ton were recorded in copper ore from 30 miles North West of Meekatharra, on Yoothapina Station.

From Arthur River, 20 miles East of Mt. Dalgety and 15 miles East of Mooloo Downs, copper ores assayed from 4 to 10 dwt. of silver per long ton.

From 12 miles East of Williambury, four mineral samples assayed from 1-14 dwt. of silver per long ton.

Lead samples from near Mons Cupri carried 7, 10 and 11 oz. of silver per ton.

From 3 miles East of Woodstock a lead specimen assayed 14 dwt. silver per long ton.

Lead ores from South of Onslow submitted by the State Mining Engineer assayed from 3 to 7 oz. of silver per ton.

8. Gypsum:— Less interest was displayed by the public in gypsum, this year. Samples of fine grained gypsum assaying 96.2 and 96.4 per cent $CaSO_4.2H_2O$ were received from Lake Magenta. Others from 3 miles South East of Quairading assayed 88.4 and 91.7 with salt (NaCl) contents of 0.51 per cent and 2.86 per cent respectively. A seed gypsum of fair quality was represented by samples from Peron Peninsula. Assay figures were 98.1, 99.2 98.7 and 95.1 per cent $CaSO_4.2H_2O$. Large crystals of gypsum were received from lake at Hyden. Other localities included Lake Nannine on Polelle Station and 6 miles North of Bruce Rock.

9. Heavy Sands:— (including ilmenite, monazite and zircon). Interest has been shown by firms currently producing ilmenite concentrates, in deposits which will provide reserves for future treatment at their plants. The number of heavy sands examined this year also increased because of the activities of private prospectors. Few of these activities represent systematic sampling. Samples were submitted from 16 localities on or near the coast both North of Geraldton and South of Fremantle. These contained varying amounts of ilmenite, garnet and zircon with a total "heavy mineral" content up to 89 per cent.

A feature of samples submitted this year was that 21 of the localities represented were in inland areas. Although not all prospectors realise the impractability of even large ilmenite deposits inland competing with shoreline deposits, this trend is probably due to increased interest in tin. Only two of the samples examined under this heading carried cassiterite. Approximately 2 per cent cassiterite was present with iron oxides in a sample from Marble Bar area. A trace of cassiterite was detected with ilmenite (35 per cent) magnetite (10 per cent) and silicates from Nelson Locality 1395. As distinct from the coastal sands, the inland ones usually contain a large proportion of iron oxides mainly magnetite, and are natural concentrates in creek beds, etc. An area of considerable size which aroused some interest before the Wardens Court is described as the Lake Boodoonoo Area via Mt. Magnet. Samples were received containing up to 35 per cent ilmenite. Subsequently samples taken by the Geological Survey Branch were examined with results as follows:—

Heavy Minerals (a)	TiO_2	Ilmenite	Leucoxene (b)	Magnetite
	per cent of original sample			
14	6·59	8	1	3
14	6·10	8	1	2
11	5·09	6	1	2
10	2·43	2	1	2
21	5·21	5	1	4
18	4·91	4	1	4
16	6·64	8	1–2	3
14	5·97	7	1	3
63	25·70	41	5–10	4
32	10·80	13	3	3
24	8·72	10	3	2
36	12·40	17	2–4	4
13	2·21	1	1	2
17	4·61	6	2	3

(a) Specific gravity greater than 2·85. (b) Estimated.

Ilmenite producing firms investigated the deposit also, but the current price of ilmenite (£4-5 per ton f.o.b. Bunbury) did not favour operation at such a distance from a port.

A sand from a lake 5 miles from Kojonup contained 75 per cent ilmenite with 2 per cent magnetite and a little monazite and leucoxene.

Mill products examined for an ilmenite producing firm included the tails from monazite tabling and impurities in various fractions from the separation plant. A check on chromium content in an ilmenite concentrate resulted in an assay of 0.03 per cent Cr_2O_3. Checks on ferrous iron content of ilmenite shipments have also been made. The insoluble material from monazite shipments was shown to be zircon and amorphous silica with minor titanium minerals. The amorphous silica is derived from the monazite grains.

Twelve per cent of monazite was found in the rejects from tin jigs on Hillside Station. Specimens were also identified from Tambourah Hills.

Overseas interest in various rare earth elements produced a query for minerals containing europium, gadolinium, dysprosium, holmium, erbium and terbium. While other rare earth minerals are recorded in Western Australia, the most probable commercial source is the monazite concentrates of beach sands.

Zircon concentrates for shipment have assayed around 65 per cent ZrO_2 with estimations also made for TiO_2, Fe_2O_3, Al_2O_3, P_2O_5 and SiO_2. The maximum permissible content of TiO_2 is 0.4 per cent.

Minerals represented in heavy sands which have been submitted in more massive form include rutile fragments from 10 miles West of Colga Downs and crystal fragments of ilmenite from Yinnietharra.

10. Iron.—The considerable interest in iron ore in this State in 1965 is reflected in the number of samples submitted by the public. The largest group of 78 samples was assayed for iron and phosphorus with some mineralogical determinations. These samples represented the investigation, by means of a number of bore holes, of the ore body at Mt. Gibson. Both the Mt. Gibson deposit and an area around Ravensthorpe have been of interest to Japanese companies. In the case of the Ravensthorpe samples the geologist required determination of iron, sulphur, phosphorus, copper and acid insolubles on 14 samples.

Another locality which aroused interest this year was Mt. Caudan. An early specimen assayed 50 per cent iron and 9.7 per cent manganese. A subsequent examination by the Geological Survey Branch produced samples which assayed between 26 and 60 per cent iron and 16 and 0.1 per cent manganese. Thirteen samples from the same area submitted by other interests assayed in composite 63.5 per cent iron and 0.16 per cent manganese.

The interest in this type of deposit centres on the possibility of producing from one ore, a metallurgical alloy of ferro-manganese.

This same interest was the purpose of a group of samples from Ravensthorpe.

Ores from Ravensthorpe have been examined also for vanadium.

A composite iron ore from Mt. Goldsworthy had the following content of minor elements:—

		per cent
Ti	....	0.07
V	....	0.05
Pb	....	0.0063
Zn	....	0.0057
Cu	....	0.0045
As	....	0.0013
Bi	....	0.0005
Cr	....	0.0003
Ni	.... less than	0.005
Sn	.... less than	0.005
Free SiO_2	....	0.12
Combined SiO_2	....	1.58

Magnetite bearing rock from the Northam area was examined to determine the possibility of upgrading to a useful ore. The magnetite assays 640 p.p.m. nickel, with vanadium less than 100 p.p.m.

From Robe River, core samples of pisolitic ore submitted by the Geological Survey Branch were found to consist of hematite with maghemite and a little goethite.

Treatment of the many iron ores submitted by the public depended on the nature of the sample. Where the sample was obvious specimen material a mineralogical description was generally sufficient examination. Other material was assayed if it represented a reasonable tonnage of ore, or if the value of the material could not be assessed without chemical examination.

Deposits at the following localities were represented by samples received.

Locality	Iron per cent	Mineralogy
Babakin	61	Mag, Go, He
Barrows Well	....	He, Go, Mag
Bencubbin	52	
Boddington, 6 miles North-East	....	He with Go
Brookton	....	Mag, He, Go
Bruce Rock, 4 miles East	....	Mag
Bullfinch	54	
Busselton, West	37, 34	
Cogla Downs	....	Mag
Coppins Find, 5 miles North	....	He (micaceous)
Corrigin	59	Mag, He, Go
	46	Go
Eudamullah-Mt. Phillip Station	50	Laterite
Gorge Rock	55	Go
	62	Mag, Go, He
Hillside	....	Mag
Jerramungup	....	Go
Jitanning	....	He
Kundip, 5 miles South-East	52	
Kununurra	56	
Meekatharra, 8 miles South	....	He, Go
Meekatharra, 38 miles North	63	Go, He
	69	He (micaceous)
Mooloo Downs	....	He
Mt. Barker, 20 miles North	61	He, Go
Mt. Caudan	50	
Mt. Gibson	....	Quartz, He
Mt. James	....	He (micaceous)
Mt. Magnet, 30 miles East	....	He intergrown with ilmenite
Mt. Phillip	....	He (micaceous)
Nannup	43, 46	
Nornakin	59	Mag, He
	58	He, Go
Ongerup	....	Go
Ravensthorpe	26, 22, 25, 24	
Roy Hill, 5 miles North	59	
Scott River	43, 49, 27, 48	
	45, 43, 41, 40	
Toodyay, 25 miles North	57, 44	
Tuckinarra, 12 miles South	62	
Waldburg Station, 15 miles West	57–23	Go and quartz
Wogalin	62	He, Mag with Go
Wydgee Station	....	Mag
Yalgoo	....	He, limonite
Yalgoo, 2 miles South	....	Go, He
Yalgoo, 10 miles North	42	Go and limonite
Yellowdine, 2 miles East	....	Mag, He, Go
Yinnietharra	....	Mag sand, He

Abbreviations: He hematite
Go goethite
Mag magnetite

11. Lead.—The increased interest shown in lead this year is reflected in the considerable increase in samples submitted for examination. A large part of this increase was due to the treatment of a number of lead ores at the Northampton State Battery. The separation achieved by the Battery produced concentrates averaging 69.3 per cent and tails averaging 2.70 per cent. For the estimation of lead content of the tails the atomic absorption spectrophotometer was used, but because of the great dilutions which would have been necessary for the concentrates, the chromate gravimetric method was preferred.

To assist the Battery in its separation technique a sample of tailing was separated by Tyler screens between 5 and 200 mesh, into eight fractions and assayed. The 1.68 per cent lead in the sample was distributed throughout all the 8 fractions although approximately 25 per cent was -200 mesh and 46 per cent between 5 mesh and 16 mesh.

Five samples submitted by the State Mining Engineer, from Uaroo, assayed 22.6 per cent to 60.6 per cent lead with a silver content varying from 5.8 oz to 14.9 oz per ton. A further three samples from Rous Creek ranged from 11.0 to 27.6 per cent lead and 3.1 to 7.8 oz of silver per ton.

Assays for which fees were charged remained the same as 1964, and again consisted of sales parcels submitted by mineral dealers.

A suite of 5 samples in connection with a claim lodged against the Main Roads Department for removal of tailings from a mineral lease in the North West were split for "Umpiring" and assayed for lead, copper and zinc.

Galena was found at a new locality at Coppermine Creek near Fitzgerald River. The sample assayed 2.77 per cent lead and 1 oz 18 dwt silver.

From the Old Comstock Leases near Mons Cupri two samples assayed 58.2 and 40.2 per cent lead respectively and silver 10 oz 11 dwt per ton and 11 oz 2 dwt per ton. The main lead mineral in these samples was cerussite but also identified were beudantite (hydrous lead iron arsenate) and plattnerite (lead oxide). Tripuhyite, a brown friable antimonate of iron, was also noted.

Interest was aroused in the Devonian lead mine at Narlarla when it was reported that a sales parcel for lead and zinc from this mine, had been paid a premium for cadmium content. Previously submitted samples were re-examined with the following results:—

	Lead, Pb per cent	Zinc, Zn per cent	Cadmium, Cd per cent
A	28.1	1.25	0.05
B	28.7	13.9	0.18
C	7.0	50.6	0.24

No discrete cadmium mineral was recognised.

A suite of samples from this locality has been added to the Departmental collection.

12. Lime—including burnt lime, limestone and lime sands.—The increased number of lime bearing samples examined this year was related to two investigations undertaken by the Engineering Chemistry Division. Semi-complete analyses were made of head samples from various localities in connection with an investigation into methods, other than by rotary kiln, for the calcination of limestone. Coarse and fine products of experimental calcines at various temperatures were examined for free and combined lime. The possible combination of lime with alumina and silica at various calcining temperatures was examined.

A second investigation by Engineering Chemistry Division into the recarbonation of hydrated lime produced an analytical problem, in that the free lime which was of interest in the products, was a very low percentage constituent. The objective of producing calcium carbonate of -300 mesh sizing for use as a seed pelletising agent meant that "free alkalinity" had to be strictly limited. pH measurements were found to give variable results dependent on time of solution, the residual uncarbonated lime being apparently protected from solution by a carbonate coating.

Line samples of production from a firm producing pre-mixed lime putty were analysed to a near complete level.

The examination of Tender Board samples of lime supplied to various State Batteries was continued this year.

Samples from the general public fell into two groups. Firstly limestones submitted by farmers interested in a soil top dressing, who suspected a phosphorus content in the samples. A second group reflected the interest of a proposed steel works in limestone as a flux.

Near complete analyses were made on limestones sought for fluxing purposes, which were submitted from a bore sampling program of the Geological Survey Branch. The areas represented included Point Peron, Rockingham and various lakes in the vicinity.

Two limestone samples were submitted by a firm requesting tests for silica content and "hardness." Hardness tests relative to Mohs scale were carried out but it was shown that the property of interest was "toughness" due to fine crystallisation of calcite rather than hardness.

13. Lithium minerals.—Petalite was the only ore of lithium of which a commercial parcel was handled this year. This production was a by-product of operations in a feldspar quarry. Shipments to Japan were represented by samples which assayed between 3.72 and 4.63 per cent lithium oxide, Li_2O, with iron, Fe, between 0.02 and 0.10 per cent. Associated with weathered petalite was some eucryptite and a pale pink platy alteration product, of the chlorite group. The pink colouration is due to traces of manganese.

Specimens from Tantalite Hill and a locality 1 mile North assayed 4.32 and 4.03 per cent Li_2O.

Amblygonite from a new locality at M.C.27 Dalgaranga, had the highest lithia figure recorded at these Laboratories (Li_2O, 9.51 per cent).

Five specimens of montebrasite from the Cattlin Creek pegmatite showed an alteration to kaolin and other clay minerals in a compact rim around unaltered material.

Spodumene examined from Pilgangoora was associated with black feldspar and a columbotantalite.

A lepidolite assaying above the commercial minimum of 3.5 per cent Li_2O was received from Stinking Pool between Wodgina and the West branch of the Turner River. Both the Li_2O percentage of 6.03 and iron, 0.69 per cent, were high but it is possible that fresher material may carry less iron.

Two other localities represented by lepidolite samples were 14 miles South of Windimurra Station and 2½ miles North West of Lakeside Station. This last occurrence is associated with zinnwaldite. The lithia content varied with degree of weathering between 2.76 and 0.53 per cent Li_2O.

14. Manganese.—No price has been quoted on the market for Australian manganese ore this year and sales have been arranged by private contract. Very few sales parcels have been examined and one only was assayed as Umpire in a dispute.

A saleable grade remains one assaying more than 45 per cent manganese with analyses required for iron, silica and phosphorus.

Late in the year Japanese interests were buying special ore for production of metallurgical alloys, but only in 10,000 ton minimum lots. The requirements are for a combined iron and manganese content between 54 and 57 per cent with manganese 38 to 35 per cent and iron a minimum of 16 per cent.

Samples submitted by the general public included pyrolusite from Nullagine; cryptomelane and psilomelane from 3 miles West South West of Lakeside Station; cryptomelane with geothite from Wittenoom; and from Coppermine Creek near Fitzgerald River, pyrolusite and cryptomelane. From 10 miles upstream on the Fitzgerald River a specimen representing a commercial grade ore was received.

(13)—25843

15. Phosphatic rock:— The Government policy implemented this year to encourage prospecting for phosphates has influenced some large mining groups to take up reserves. In conjunction with this activity the Geological Survey Branch has submitted samples from a number of localities, which were assayed with the following results:—

Locality	P_2O_5 per cent range
Carnarvon, 33 miles North-West	0.03, 0.05
Carey Downs Station, 20 miles South-East	1.01
Cundlego Well	0.26–6.03
Dampier Downs, Kimberley	1.87, 1.27
Deepdale, 6 miles North-West	0.05, 0.16, 0.21
Geraldton, 14 miles East	1.24
Greudna Well	0.09
Kimbers Well, Middalya Station	0.18
Kimbers Well, 2 miles North-East	0.19–10.8
Lyndon Station, 31 miles South	0.11–0.19
Myroodah, Kimberley	0.50
Pelican Hill, Carnarvon, ex bore	0.15–1.06
Rough Range No. 1	0.78, 1.12, 0.33
Winning Station, 34 miles West-North-West	0.24–2.01

A number of samples examined for a consulting geologist and for private prospectors all assayed less than 0.10 per cent P_2O_5.

A donation of three phosphate minerals struvite, newberyite and hannayite (?) from Mt. Widdernen Caves at Skipton, Victoria was made to the Division's collection.

Other interesting specimens were a dark red-brown triplite from a new locality 3 miles South of Mt. Alexander and a variscite associated with opaline material and a green apatite from Yinnietharra.

16. Salt:— A most interesting sample of rock salt examined was from 4215 ft to 4225 ft in Willara No. 2 Well.

The salt was accompanied by a reddish silty claystone and the water soluble material was analysed with the following results:—

	per cent
Sodium, Na	38.7
Potassium, K	0.04
Lithium, Li	0.03
Calcium, Ca	0.37
Magnesium, Mg	0.04
Chlorine, Cl	59.8
Sulphate, SO_4	1.04

Other samples included one from Boxwood Hill area with 50 per cent halite associated with clay, and halite with epsomite and silicate minerals from an undisclosed locality.

17. Silica sands:—Silica sands assumed an importance for purposes other than as a concrete aggregate when the Department of Industrial Development established that a demand existed in Japan for silica sands for glass manufacture. Previous supplies were obtained from South Vietnam and an Australian analysis was required for comparison with an analysis of accepted material.

The analysis of — 30 + 60 mesh material from South Vietnam was as follows:—

	per cent
Fe_2O_3	0.02
TiO_2	0.04
Al_2O_3	0.06
SiO_2	99.66
Other impurities	0.22

On behalf of the Department of Industrial Development samples from three operating sand pits were examined and bench scale upgrading tests applied with the following results:—

—	Pit 1			Pit 2			Pit 3		
	A	B	C	A	B	C	A	B	C
	per cent			per cent			per cent		
SiO_2	99·0	99·3	99·3	99·6	99·8	99·8	99·8	99·9	99·8
Fe	0·077	0·028	0·023	0·029	0·008	0·007	0·011	0·004	0·005
Ti	0·121	0·055	0·041	0·098	0·038	0·041	0·044	0·026	0·029
L.I.	0·26	0·26	0·26	0·09	0·09	0·08	0·08	0·08	0·08
N.V.R.	0·71	0·42	0·45	0·31	0·13	0·16	0·10	0·05	0·08

L.I. Loss on ignition.
N.V.R. Non-volatile residue.
A As received.
B After washing and screening to + 100 B.S.S.
C After magnetic separation of impurities.

Analyses were also made for several private investigations, some of which indicated good grade sands.

Samples from various depths in the vicinity of Lake Gnangara were examined and found to be of high quality.

From 4 miles East of Gingin on the Gingin-Mooliabeenie road a sample was examined of a sand which could be useful after upgrading.

Initial chemical work on these sands was invalidated by contamination from grinding machinery. Subsequent precautions overcame this problem.

18. Tantalum and Niobium:— The tantalum minerals examined this year were approximately the same in number as 1964. Whereas in 1964 the number was largely made up of submissions in connection with an investigation of the State Mining Engineer, in 1965 the largest group was of commercial parcels of concentrates with a large number of free public determinations.

Accurate determination of percentages of Ta_2O_5 and Nb_2O_5 were made by chromatographic separation and estimation of total combined oxides (Ta_2O_5 + Nb_2O_5) and of Ta_2O_5. Where applicable, the grade of samples was estimated by specific gravity measurement.

From the Dalgaranga Field, concentrates often included tapiolite and microlite with tantalite and columbite. Parcels assayed up to 72.9 per cent Ta_2O_5 and down to 37.0 per cent Ta_2O_5. A typical assay was Ta_2O_5 65.3 per cent, Nb_2O_5 5.4 per cent. One sample submitted in connection with the setting up of a new separating table, assayed 26 per cent acid soluble iron indicating a content of hydrous iron oxides of up to 43 per cent.

Samples received from the Pilbara area were variable in composition with Ta_2O_5 63 to 34 per cent and Nb_2O_5 21 to 47 per cent.

From Londonderry one parcel assayed 37.6 per cent Ta_2O_5 and 41.2 per cent Nb_2O_5.

Six concentrates from a consulting geologist in the Greenbushes area assayed Ta_2O_5 36-53 per cent and Nb_2O_5 19-27 per cent.

A number of other parcels were examined from unknown localities.

Localities represented by samples examined at public expense include the following:—

	Ta_2O_5	Nb_2O_5
	per cent	
Balingup, 6 miles South East	68	16
Castlemaine Creek	39	48
Hillside Station, 5 mls. East (Pilbara)	46	37
Mt. Charles via Cue, 8 mls. Nor' Nor' West	30	51
Paynes Find, 1 mile South	42	40
Lakeside Station, 3 miles North West	4	75

A new locality recorded for tantalite (Ta_2O_5 75 per cent, Nb_2O_5, 10 per cent) was at Chiritta on the Maitland River.

A specimen from the Northern Territory was identified as tapiolite.

Tanteuxenite and fergusonite were identified in discards from a jig on Hillside Station, in the Pilbara G.F.

19. Tin.—The sustained high price for tin during 1965 brought more producers into the field with a rise of more than 100 per cent in the number of samples submitted for examination by this Division.

The largest group of samples was from mineral dealers checking sales parcels in transit to Eastern States smelters. Of 84 samples submitted in this way only four were sent to Umpire as varying between analysts by a greater amount than the acceptable difference of 0.5 per cent tin, Sn. Spectographic analyses were obtained from the Agriculture Division of two standard ores from the U.S. Department of Commerce, as a continuation of the study of analytical difficulties with tin. Trouble had been experienced with the iodimetric titration method with the Bolivian ore but not with the Netherlands East Indies Ore. The spectrographic analysis revealed no significant differences in minor elements present, the main difference between the two ores being the large amount of iron oxides in the Bolivian ore.

A feature of trading in tin this year has been the introduction of a penalty for concentrates assaying more than 7 per cent iron. This is a protection against a number of ores carrying large amounts of magnetite.

The interest shown in small quantities of tin in soils has produced a number of samples for assay in the order of 100 parts per million of tin, this being the lower order of tin content commercially recoverable. The most satisfactory method of handling these to date has been a concentration of the cassiterite content by heavy liquid followed by an iodimetric titration.

Three soils from Cue assayed 420, 20, and 330 parts per million while samples submitted by the Geological Survey Branch from Poona in the Murchison contained 50 and 2,000 parts per million.

Three sites on Hillside Station (Pilbara) were represented by soil samples. Three miles North of the homestead the top soil carried 2.4 per cent heavy minerals including 0.69 per cent tin, Sn. A second sample carried 0.9 per cent heavy minerals with 0.31 per cent tin, Sn. From 5 miles East of the homestead two soils assayed 1.39 lb per long ton and 0.19 lb. per long ton while a "yandied" concentrate consisted of 88 per cent cassiterite with columbite and iron oxides. Shed Mill Creek on Hillside (Pilbara) was the site of an interesting sand, mainly quartz, feldspar, iron oxides and clay with rutile, euxenite, zircon and monazite, and 1 to 2 per cent cassiterite.

The old M.C.20 at Holleton was represented by a sample assaying 1.75 per cent tin. A suite of samples was assayed later from a new mineral claim at Holleton.

On Binneringie Station, 12 miles East of Paris G.M. a sand consisting of albite, quartz and mica assayed 0.39 per cent tin. Subsequent samples assayed 0.003 and 0.061 per cent tin. A cassiterite fragment from this site weighed 110 grams.

Pegmatites in various localities have yielded payable amounts of tin during the year. From six miles South of Norseman on P.A.2595 a sample of pegmatite with feldspar, quartz and lepidolite contained cassiterite equivalent to 4.45 per cent tin, Sn, with some tourmaline. A second sample assayed 1.38 per cent tin.

No tantalo-columbite minerals were detected in these samples, or subsequent ones taken on the site by an officer of the Division. This freedom from other heavy minerals has allowed the separation of commercial parcels of cassiterite by simple crushing and tabling at the State Battery. A concentrate prepared in this way assayed 60.4 per cent tin, Sn.

At Pilgangoora a pegmatite has been sampled which contains albite, quartz, beryl and mica with some cassiterite and columbite. Two Prospecting Areas registered by the Native Welfare Department yielded samples assaying as follows.

On Mt. York—8.83, 1.09 per cent tin.

3½ miles South of Mt. York—6.90 per cent tin.

A small amount of cassiterite was observed in a pegmatite sample from Serpentine Loc. 454 CG consisting of feldspar, quartz, tourmaline, goethite and muscovite.

Natural concentrate samples from Castlemain Well, 7 Miles South South East of Nullagine ranged from 55 to 65 per cent cassiterite and 12 to 20 per cent columbite with monazite, iron oxides and silicates and 1 to 5 per cent of bismuth carbonate minerals. No bismuth minerals have previously been reported from this locality. Another similar sample from Nullagine contained 94.6 per cent cassiterite.

Other tin bearing samples included one from 3 miles West of Pinga Well on Abydos Station consisting of approximately 93 per cent. cassiterite and 7 per cent magnetite. Cassiterite with minor tourmaline, quartz, mica and iron oxides was received from Nelson Loc. 3,600. From Nelson Loc. 1395 a sample contained 79 per cent cassiterite, and 5 per cent columbite with quartz, ilmenite, magnetite and silicate minerals.

It is worthy of note that a number of persons submitting samples use the terms tin and cassiterite synonymously, thus leading to some confusion regarding values.

Records of samples assayed chemically and estimated from mineralogical examination show good agreement when a factor of 0.95 is applied to the cassiterite percentage obtained from mineralogical examination.

20. Tungsten:— Although no market price is quoted for scheelite, the more common ore of tungsten in this State, some parcels of concentrates have been sold this year by negotioation with buyers. The price, though variable, has been based on a figure of £750 per ton of concentrates assaying 65 per cent tungstic oxide WO_3. Parcels sold have generally assayed below this figure.

Interest has centered mainly on the area South of Coolgardie particularly at Higginsville. The concentration of scheelite in the dumps of abandoned gold mines has prompted attempts at separation, and a saleable grade of concentrate has been shown to be obtainable by gravity separation followed by removal of magnetics. Both steps are necessary to produce the required grade.

Sands from 3 miles South of Coolgardie assayed of the order of 100 parts per million WO_3 while some from 25 miles South East assayed 0.012 per cent WO_3. From Westonia, sands assayed up to 640 parts per million WO_3.

Scheelite specimens were received from Melville and Marble Bar. The latter specimen carried, as an alteration product, a thin film of ferritungstite

From Northampton a specimen of ferberite was received.

21. Vanadium:—The source of a reduced number of samples examined this year for vanadium was largely individual prospectors.

A large number of samples from Ravensthorpe, Northam and Williambury all contained less than 0.01 per cent V_2O_3.

From Barrambie a sample consisting of hematite, magnetite, limonite and quartz assayed 0.66 per cent V.

A sand from Yinnietharra consisting of 80 per cent magnetite assayed 0.1 per cent V.

Other samples examined were from undisclosed localities.

Analytical work associated with upgrading research by the Engineering Chemistry Division, on material from Coates Siding, is reported under "complete analyses."

22. Other Ores and Minerals.

Alkalis—other than common salt and lithium. A series of 67 acid volcanic rocks from the Woongarra Volcanics of the Hamersley area were assayed for sodium and potassium.

Antimony—The only material submitted assaying more than 60 per cent Sb, the minimum specified for sales parcels, was specimen material from 26 miles East of Nullagine consisting of a core of stibnite and quartz, with stibiconite and valentinite. A specimen of stibnite, quartz and stibiconite was received from 1 mile North East of Nullagine. From 2 miles South of Wiluna a specimen of stibnite assayed 31 per cent Sb and one of stibiconite assayed 53 per cent Sb. Dump material from Wiluna assayed 0.92 per cent Sb. A specimen of tripuhyite was received from near Mons Cupri.

Bismuth — A yellow mineral present in trace amounts in a rock from 20 ft. down an open cut between the railway station and town dam at Menzies was identified as pucherite (bismuth vanadate). Bismuth carbonate minerals in small amounts were recognised in mineral samples from 5 miles South West of Castlemaine Creek. A specimen of bismutite was received from the Morrisey Ranges near Yinnietharra.

Cobalt—A sample of cobaltite from an undisclosed locality as submitted by a prospecting company and assayed 13.0 per cent Co, 0.41 per cent Ni and 0.08 per cent Cu. From Ravensthorpe a sample assayed 11.9 per cent Co. Other samples examined assayed less than 0.1 per cent Co.

Mercury—Three mineral samples were submitted for check assay for mercury, by the Kalgoorlie School of Mines. Three methods with overlapping ranges of effectiveness were investigated. Good agreement was obtained between these methods in the areas of overlap. Assay results were as follows—

	Mercury, Hg per cent
1. Pyritic concentrates	0.017
2. Pyritic concentrates	0.032
3. Telluride concentrates	0.26

Molybdenum—One specimen only of molybdenite was received during the year. It occurred in quartz 14 miles South of Rothsay.

Advice has been received from Mr. G. H. Riley that work has been completed and publication is at hand on a rhenium concentration study of molybdenite from various localities, for which Western Australian specimens were provided in 1963. This work was done at Lucas Heights.

Nickel—A number of samples were examined which were barren of any nickel, but carried a green colouration. In a series from an undisclosed locality, submitted by a prospecting firm, the highest content of nickel was 1.19 per cent. Other localities from which nickel was recorded, with their percentage nickel contents are as follows:— Goongarrie, 3 miles South, 0.16; Goongarrie, 1½ miles North, 0.33, 0.28; Jerramungup, 0.02; Norseman, 18 miles North, 0.19; Norseman, 8 miles North-West, 0.14; Northam area, 0.45; Mt. Newman iron ore camp, 25 miles South, 0.22, 0.04; Dundas, 12 miles South, 0.003.

Platinum group metals—Two samples submitted which were suspected to contain these metals came from Greenbushes. One contained no osmiridium, iridium or platinum, while the other contained less than 0.1 p.p.m. platinum.

Zinc.—Specimen of blende were submitted from Geraldine; 3 miles East of Geraldine; and Harrismith, West of the rabbit proof fence. Smithsonite and hydrozincite were identified in a group of specimens from the Devonian lead mine at Narlarla.

MINERAL IDENTIFICATIONS

1. New species. Work is proceeding towards publication of data on three species of mineral not previously described.

2. New localities. Mineral species, for which new Western Australian localities were recorded at these Laboratories in 1965, are listed below. Those marked with an asterisk represent the first Western Australian occurrences reported from these Laboratories.

Mineral	New Locality
	(a) Kimberley Division
Anatase	Montague Sound
Boehmite*	Montague Sound
	(b) North West Division
Amethyst	? Master Mine, Mt. deCourcey, Wyloo.
Beudantite	Mons Cupri.
Bismutite	7m. S.S.E. Nullagine.
Celadonite	Jiggalong.
Chalcocite	(1) 6m. S.S.W. Mt. Blair. (2) 15m. S.E. Yandicoogina.
Covellite	15m. S.E. Yandicoogina.
Cuprite	6m. S.S.W. Mt. Blair.
Digenite	15m. S.E. Yandicoogina.
Ferritungstite	Marble Bar area.
Fluorite	15m. W. Hillside Homestead.
Malachite	6m. S.W. Mt. Blair.
Plattnerite*	Mons Cupri.
Tantalite	Near Chiritta on Maitland R.
Triplite	3m. S. Mt. Alexander.
Tripuhyite*	Mons Cupri.
	(c) Murchison Division
Anthophyllite	Mooloo Downs.
Baryte	10m. W. Mt. Seabrook.
Chalcocite	2m. N. Murchison R. Bridge.
Corundum	Pindar.
Cuprite	Ogilvie.
Digenite	2m. N. Murchison R Bridge.
Idocrase	Big Bell.
Lepidolite	Lakeside Station.
Montebrasite	No. 27, Dalgaranga.
Palygorskite	Nooka Leadmine, Northampton.
Topaz	Lakeside Station.
	(d) South West Division
Blende	Harrismith.
Brushite*	Jurien Bay.
Galena	Coppermine Creek near Fitzgerald R
Gypsum	Jurien Bay.
Natrojarosite	8m. S. Nungarin.
Phenakite*	1m. S. Paynes Find.
	(e) Central Division
Alunite	2m. S. Victory Reward Claim in Breakaway Group.
Arsenopyrite	Eundyne.
Holmquistite*	Mt. Marion.
Laumontite	Londonderry.
Pucherite	Menzies.
Stilbite	Londonderry.
	(f) Eastern Division
Calcite	Vicinity of Mt. Brophy in Warburton Ranges.
Opal	Vicinity of Mt. Brophy in Warburton Ranges.
	(g) Eucla Division
Cassiterite	6m. S. Norseman.
Natrojarosite	15m. N. Norseman.
Petalite	6m. S. Norseman.

First recorded occurrences—

Boehmite was recorded for the first time in Western Australia in bauxite from Temporary Reserve 3500H at Montague Sound, see under Bauxite.

Brushite.—Further work is being done on brushite found in powdery mixture with gypsum in a cave at Jurien Bay. X-ray data obtained resemble more closely the pattern of artificial $CaHPO_4.2H_2O$ than the A.S.T.M. pattern for brushite.

Holmquistite.—A specimen verified as the orthorhombic amphibole, holmquistite, was donated by the C.S.I.R.O. Secondary Industries Laboratories, from a locality near the lithium bearing pegmatite at Mt. Marion.

Phenakite occurring as a minor intergrowth with beryl was identified from 1 mile South of Paynes Find, see Beryl.

Tripuhyite and Plattnerite.—Samples from the old Comstock Leases near Mons Cupri consisting essentially of cerussite with quartz, hematite, goethite and galena, contain small amounts of tripuhyite and plattnerite (see respectively Antimony and Lead).

3. Mineral collections.—During this year 144 specimens were added to the Mineral Division Collection (M.D.C.) Nos. 3593-3736. Two specimens entered into the collection last year, by exchange from overseas, were found, on further work, to be wrongly identified.

From localities and workers outside the State donations numbered 26.

Two specimens of colerainite from Chester County, Pennsylvania, U.S.A. were donated by the Department of Mineral Sciences, Smithsonian Institution, U.S. National Museum.

One further addition from the estate of the late Mr. J. Jelly of Kalgoorlie was a specimen of chlorargyrite from Broken Hill, N.S.W. From Broken Hill also, donated by the Geological Survey Branch, was pyrosmalite (variety manganpyrosmalite) associated with quartz, garnet, blende and galena.

Other donations include fluorite from Derbyshire, England; monazite and beryl from Galah Creek via Mt. Isa, Queensland; stilbite associated with actinolite and sphene from the old Ankaroola Bore, North Flinders Range, South Australia; triboluminescent dolomite from Razorback, Dundas, Tasmania; prehnite associated with calcite from Prospect Quarry, Sydney, N.S.W.; thomsonite with calcite and stilbite from Simons Bay, Victoria; laumontite replacing fossil wood from Point Gregory, Victoria; torbernite in ironstone from Mt. Painter, South Australia; prehnite, calcite and pumpellyite (fine needles) in basalt from New Jersey, U.S.A.; heazlewoodite from Mt. Bischoff, Tasmania; native bismuth with feldspar from Cobalt, Ontario, Canada; topaz from New England Ranges, N.S.W.; apatite from Durango, Mexico; celestite from Cornwall, England; cinnabar from Almaden, Spain; rhodonite with tephroite from Utah, U.S.A.; tetrahedrite, rhodonite and pyrargyrite from Rosebury, Tasmania; and stillwellite. allanite and garnet from Mary Kathleen, Queensland.

Additions to the collection from Western Australian sources numbered 118 and represented donations from the University of W.A. and various Government Departments, mining firms and individuals, and are described in the text under Ores and Minerals.

Eighteen collections representing economic minerals were provided as study aids to students and prospectors.

As in previous years, a policy was maintained of conserving specimen material by refusing requests for collections from individuals outside this State. Six requests this year were referred to dealers in mineral specimens and to the Lapidary Club of Western Australia.

Material, including osarizawaite, wodginite and stuverite, has been supplied to other workers in mineralogy.

Details of sixteen fossil wood specimens in the Department's collections were supplied to the University to assist an investigation planned there.

In response to a request from the Division of Applied Mineralogy C.S.I.R.O. a specimen of cobaltite was loaned together wth a crushed remnant from analysis to assist a study on crystal symmetry.

Analysed samples representing six commercial ores were provided to the Western Australian Institute of Technology for use as assay standards.

4. Miscellaneous Minerals.—The number of samples submitted for mineral identification, on which some laboratory work was necessary was at the same level as 1963 and somewhat higher than 1964. As in previous years the great preponderance of these submissions were done free for the public. Where positive identifications by inspection were possible the samples were not registered for laboratory work.

Amongst the miscellaneous minerals examined the following are of more than usual mineralogical interest.

Ferritungstite is a mineral which is probably fairly widely spread as an alteration product of tungsten ores but is rarely reported. Material from six Western Australian localities is represented in the Simpson collection. A recent paper has described the mineral as a hydrous calcium ferri-ferrous tungstate with tetragonal symmetry. The published X-ray patterns match those for the local mineral which are in turn virtually identical with patterns of stibiconite, a cubic mineral with a pyrochlore structure. Qualitative tests of the purest local mineral available showed that ferrous iron was absent.

The lithium aluminium silicate, eucryptite, in coarsely crystalline form at the Londonderry quarries, was positively identified only after comparison with the data of C. S. Hurlbut (1962) Am. Min. 47, p. 557. Previously published optical data were incorrect and X-ray powder data was not listed in the A.S.T.M. Powder Data File, so that early indentification was made solely on composition.

It is regretted that in references to perite in this Division's Annual Report of 1964 full recognition was not given to the work of Dr. Gilberg. The full text of this work was not available at these Laboratories at that time.

γ-alumina, which is unstable at normal temperatures, was identified by optical and X-ray data, associated with α-alumina (corundum), in a hard black "laterite" pebble from Greenbushes. γ-alumina has not been reported as a naturally occurring mineral and it has been assumed that the mode of origin of this specimen has been dehydration of gibbsite by bush fires.

Beryl from 1 mile South of Paynes Find was found to contain a small amount of phenakite, optically identical with a collection specimen of phenakite from Norway.

A small amount of white laumontite was found in a pink, manganese stained, mixture of chlorite and quartz from Londonderry Quarry.

Lapidary and art specimens have been found in minerals which are grouped, for that reason, in this section, although few of these occurrences are of value. Fine collection specimens of amethyst have been donated from Mt. de Courcy. Rock crystal was recorded at Howatharra and Lake Grace, Tourmaline from Whim Creek, 27 miles East and Peak Hill, 5 miles West, was black, while green crystals were submitted from Wodgina, and blue from an undisclosed locality. No occurrence of precious opal was recorded, but good quality common opal was submitted from 40 miles North of Leonora. Poor quality material was also received from Nelson Loc. 12143; from Warburton Ranges in the vicinity of Mt. Brophy; Marble Bar, 50 miles North East; Westonia 3 miles West; and from the 32 mile peg on the No. 2 Rabbit Proof Fence.

A similar grouping is made of abrasive materials although natural abrasives have very little demand now in competition with assured regular supplies of artificial abrasives. Blue corundum with small amounts of mica was received from Pindar, and corundum crystals with ruby colour, but below gem quality, from 4 miles East of Quairading. Diatomaceous earth was received from the Elleber swamps and spongalite from Kukerin. Garnet was submitted as crystals in biotite schist from Wittenoom, and in beach sands from many localities including 93 per cent of a sand from Windy Harbour. A black garnet from 2 miles North West of Comet Vale submitted in 1963 was further examined. Chemical analysis indicated theoretically that the garnet was a mixture of andradite 37 per cent), grossularite (52 per cent), almandine (6 per cent) spessartite (1 per cent) and pyrope (4 per cent).

Other mineral identifications made include:

Actinolite—green crystals and white fibres with altered mica from Nullagine.

Alunite with 9.32 per cent K_2O submitted by Geological Survey from 2 miles South of Victory Reward at Ryans Find.

Anthophyllite from Mooloo Downs, and weathered, with talc, from ½ mile North of the old Rothsay G.M.

Baryte of good grade with a slightly off white powder was submitted from the Roebourne area; from Winning Pool, 250 miles South West of Roebourne; and from 15 miles North of Moorarie Station homestead. Specimens from Kununurra and Mt. Phillip Station had some limonite staining. Baryte with galena was examined from the Murchison River near the Carnarvon road.

Bitumen was submitted in a sample from cavernous limestone at a depth of 30 ft. on Barrow Island. This sample and one with beach sand from an undisclosed locality, were both true bitumen, not bat guano.

A chromite specimen handed on from the Kalgoorlie School of Mines, Geology Department, originated 12 miles South East of Byro Station and assayed 34.3 per cent chromium and 22.9 per cent iron. Chromite was the essential constituent, together with ilmenite, iron oxides and silicates with free gold, of a sand at Mundy Hill near Yellowdine. An interesting specimen of magnesio-chromite which assayed Cr_2O_3 58.9 per cent, Al_2O_3 12.2 per cent, and MgO 13.1 per cent was received from a locality near Ravensthorpe.

Crocidolite in an interesting form came from a locality approximately 20 miles South West of Wittenoom. Fragments of crocidolite veins and jaspillite occurred in breccia in a matrix of white irregularly layered calcite.

Feldspar in pale green form was received from North of Paynes Find.

Purple fluorite with green beryl crystals in feldspar occurs 15 miles West of Hillside in Tombourah Hills.

Natrojarosite with yellow iron oxides, quartz and halite occurs at two localities, 8 miles South of Nungarin and 15 miles North of Norseman.

Kyanite was received from two known localities at Smithfield and the Chittering Valley.

Magnesite from 7 miles West of Nukarni had an approximate composition 88.7 per cent $MgCO_3$, 4.8 per cent $CaCO_3$ and 4.9 per cent insoluble material, mainly silica.

Ochres examined include one from Corackerup with good covering capacity but relatively dull colour. A poor sample from 20 miles East of Perenjori was found to be largely clay with yellow iron oxides and one from ½ mile North West of Wilgie Mia cave had only 15 per cent iron and had very poor covering capacity.

A colour comparison was made on behalf of a client, of imported ochre and a local one on offer. A mix was made of the recommended strength of ¼ cement, ¾ sand and 20 lb. of imported pigment per ton. A comparable mix was made with local oxide added to produce the same colour intensity. It was found that 20-30 times as much local material was necessary for the same effect as the imported.

Prehnite was identified in a specimen from Londonderry.

Pyrite apparently representing massive material was submitted from 18 miles South East of King Peaks (Beagle Bay) while specimens from Meekatharra were not in massive form.

Twinned crystals of staurolite from 20 miles East of Yinnietharra homestead occurred in hornblende.

Green coarse grained talcs from 6 miles South West of Yarraquin homestead and 20 miles South East of Cue, both ground to good white powder. A specimen from Fields Find consisted of kaolin and talc in the approximate ratio of 3:1. A complete analysis (q.v.) was made of a talc from U.S.A. for the University.

5. Spurious Minerals.—Several samples of ferro silicon were submitted, and a solder was found at Larkinville.

Crushed material from the vicinity of Bullfinch had a panning tail of artificial carborundum.

A white powder formed within a rotary kiln used for burning limestone was found to be the γ form of di-calcium silicate, γ $2CaO.SiO_2$.

Other artificial minerals examined were the products of heat treatment of arsenic minerals.

Speiss from old gold mining dumps at Wiluna were analysed for iron, arsenic, antimony, lead, gold and silver.

6. Fossils.—Molluscs of terrestial origin and Quarternary age were associated with gypsum and quartz in samples from Koorda.

Specimens of belemnite "guards" which have been converted from the original carbonate to quartz and chalcedony were received from 154 Disc on the Rabbit Proof Fence, 6-7 miles inland from Bluff Point, North of Northampton.

From Borden came a specimen of silicified wood. Further specimens in curious weathered forms were from a lake 20 miles East of Cranbrook.

Submitted from 21 miles from Mt. Magnet on Yalgoo road, was a specimen of "nest" produced by Leptoplus—a beetle which is still living although there is evidence that such "nests" found elsewhere are of considerable geological age.

7. Meteorites and Tektites.—Specimens of tektites were submitted from Yellowdine Lake area.

An iron meteorite of the common medium octahedrite type was received from a mineral buying firm representing an unnamed client. The cooperation of the client, in advising the Meteorite Advisory Committee of the Western Australian Museum, was requested.

Miscellaneous Examinations.

1. Complete analyses.—The examination was finalised this year of 28 samples for complete silicate rock analysis, which were submitted in 1964 when 9 of the samples were analysed. These samples submitted by the Geological Survey Branch supported petrological work in the Brockman Iron formation particularly in the vicinity of the Colonial Mine at Wittenoom Gorge. This work is the subject of a report of that Branch.

A further nine rock samples associated with the Brockman Iron Formation were received and analysed this year. Their general petrological description is: carbonate rich chert; flat modified chert; massive fibred riebeckite; banded iron formation; banded siderite; three cherts; and a talc with a high refractive index due presumably to the high FeO content.

In connection with the above investigation a sample was analysed (from the banded ironstone formation at Wittenoom) and identified as stilpnomelane. The sample received consisted of a platy portion, and a massive portion which X-ray examination indicated was contaminated, possibly by epidote. Only the pure platy material was analysed with the following result.

	Percentage
SiO_2	45.54
Al_2O_3	4.75
Fe_2O_3	2.90
FeO	25.38
MgO	7.75
CaO	0.04
Na_2O	0.82
K_2O	1.96
H_2O^+	8.46
H_2O^-	1.56
CO_2	0.28
TiO_2	0.26
P_2O_5	0.44
MnO	0.13
	100.27

Analyst J. Gamble

The formula derived from these and X-ray studies is reported by the Physicist and Pyrometry Officer.

A sample of pumice found early in the year, on the beach at Yanchep had the following composition.

	per cent
SiO_2	68.47
Al_2O_3	11.92
Fe_2O_3	0.76
FeO	2.02
MgO	1.04
CaO	3.14
Na_2O	3.68
K_2O	0.58
Li_2O	0.04
H_2O^+	4.86
H_2O^-	0.79
TiO_2	0.30
P_2O_5	0.062
SO_3	0.18
NaCl	1.96
MnO	0.048
	99.85

Analyst R. W. Lindsey

Complete analyses were also done on a sample of pyrophyllite from North Carolina and a talc from Holley Springs, both submitted by the University of Western Australia, Department of Physics, in connection with a research program on the thermal expansions of these minerals.

Vanadiferous material from Coates Siding, on which a research program for beneficiation was carried out by the Engineering Chemistry Division, was analysed as follows.

	Weathered ore	Unweathered ore	
		Magnetic concentrate	Non-magnetics
	per cent	per cent	per cent
SiO_2	22·94	3·56	40·96
Al_2O_3	19·19	0·99	17·75
Fe_2O_3	33·72	52·79	6·69
FeO	3·96	27·40	12·06
Metallic Fe	n.d.	0·11	0·05
FeS_2	n.d.	0·056	n.d.
MgO	0·08	0·54	2·87
CaO	n.d.	n.d.	8·21
Na_2O	0·08	0·11	2·32
K_2O	0·32	0·05	0·39
H_2O+	11·04	1·69	2·95
H_2O-	1·67	0·12	0·50
TiO_2	6·11	11·49	3·73
P_2O_5	0·039	0·022	0·12
V_2O_5	0·42	1·12	0·12
MnO	0·13	0·25	0·18
SO_3	0·37	n.d.	1·07
Cl	*	n.d.	*

* Less than 0·01 per cent. n.d. = not detected.

Analyst : R. W. Lindsey.

2. Health hazards.—Samples examined as a health hazard were this year confined to dusts, airborne or settled. The largest group of these was collected at regular intervals by the Fuel Technology Division. They were from a number of set traps distributed to represent the dust fall out pattern in industrial areas, residential areas, etc., as a backbround to other invesigations. The microscopic nature of the dusts was recorded.

The Public Health Department submitted a number of samples following complaints of air pollution. These are generally represented in the first instance by samples of settled dust from cars, houses, garden plants but included a printing bench. The purpose of the investigation is then to attempt to recognise the source of the dust.

Materials recognised have included soot, sawdust, and minerals from rock crushing, sand blasting, acoustic spraying and from chemical plant roasters.

The Division has cooperated in taking samples of air for determination of the number of particles of dust per unit volume of air, and also in instructing officers of other Departments in the use of the Midget Impinger sampling aparatus. Samples are taken in the breathing zone of workers carrying out suspect operations. Apart from the constitution of the dust these samples are microscopically graded since material less than 5 microns in diameter has been shown to represent the greatest hazard to health.

Evidence was presented in a case before the Workers Compensation Board to establish whether the conditions prevailing at an industrial plant could have been responsible for the silicotic condition of a worker from the plant.

For the Postmaster General's Department, samples were taken and examined of air surrounding telephone exchange equipment. The dust content of these samples was at a very low level.

3. Metals, alloys and corrosion.—The samples examined under this heading each constitutes a separate investigation with the exception of one group of 110 corrosion pieces.

A mild steel plate of Japanese origin was analysed for C, Si, Mn, P and S in order that a decision could be made on the type of rod to use for welding. It was found to comply with Australian Specification A-33.

An alloy from research at the University Physics Department was found to contain 28 per cent magnesium and 71 per cent aluminium.

A cast iron from the Iron and Steel Industry at Wundowie had the following percentage constituents: combined carbon 0.10, graphite 3.45, silicon 2.62 manganese 0.47, sulphur 0.030 and phosphorus 0.031.

A silver solder in use on the building extensions at these Laboratories assayed the following percentages: silver 45.9, cadmium 24.8, copper 14.9, zinc 14.2 thus conforming with the A.S.T.M. standard for a brazing filler metal B. Ag. 1 : 1964.

A sample submitted by the Western Australian Museum for examination with minimum damage was a mortar, marked 1654, from the wreck of the Gilt Dragon off Lancelin. An analysis of the metal with some limitations due to material available is—

	per cent
Cu	74.7
Pb	10.6
Sn	6.65
Sb (a)	3.15
R_2O_3 (b)	2.95
Zn	0.58
As	0.39
Ag	0.02

(a) does not include Sb occluded with metastannic acid in seperation.

(b) predominantly oxides of Al and Fe, probably occurring in the original as metals.

Corrosion products recognised were a disordered atacamite and cuprous oxide Cu_2O, but consisted largely of a friable green material which had an X-ray pattern not recorded in the A.S.T.M. index. Technical advice re restoration was given, based mainly on published reports on investigations conducted at the British Museum.

An examination was made of two water valves of cast iron, one of which corroded in use. Metallographic examination of polished mounts indicated that corrosion was due to the porosity of the enamel coat on the attacked specimen, accelerated perhaps by the large grain size of graphite, etc., in the metal. This explanation appears more likely than suggested effects of heat treatment.

Galvanised purlins which were stacked in the open were found to be covered with a gelatinous corrosion product. The intact galvanising was tested and found to comply with Australian Standard AS.A20 for class C galvanising, but not for classes A. B and D.

A wire rope from the air hoist of a gold mine was examined when it broke after two months of use. The failure was attributed primarily to oxidation although polished mounts showed corrosion pits, and water extracts showed a higher content of SO_4 from the corroded rope.

Late this year a parcel of 110 corrosion test pieces was submitted for examination of weight loss, corrosion attack and products. These consisted of various metals supplied to the U.S. Navy in December, 1963, which had been buried since that time in the soil at the North West Cape, V.L.F. Communications Station.

A platinum wire was examined which had been found to become brittle rapidly when used in laboratory bacteriological tests by the Agriculture Department. No alloying elements known to cause embrittlement, were found. A comparison with unused platinum wire supplied, showed the only differences were a higher content of phosphorus in the embrittled wire, perhaps derived from organic specimens tested, and higher iron in the unused wire indicating an original impurity leached out in use.

A mineral substance was submitted as being the possible cause of corrosion of a platinum crucible used as a fusion vessel at a commercial laboratory. No corrosive substances were identified and a repeat of the described fusion did no damage to a sound crucible.

Three metal couplings were examined for a Planning and Design engineer. After use with corrosive bore water one had failed and was found to be unalloyed iron. The two satisfactory ones were approximately 18 : 8 stainless steel with 0.1 per cent molybdenum.

4. Cement and concrete.—Under this heading are considered 69 samples consisting of 28 samples of set concrete together with sands, coarse aggregates, cements, a locally prepared lightweight aggregate and an efflorescence from set concrete.

Set Concretes.—In all cases the set concretes were examined to determine the original mix. Often this determination was requested when the information required was rather the cause of failure. This investigation is less difficult if the chemist has the opportunity of examining the site of the failure rather than depending on samples submitted to the Laboratory.

For estimation of original mix according to Australian Standard A110—1957, examination of original aggregate, fines and cement is necessary. When these original materials are not available assumptions regarding their properties must be made, which render the final figure open to relatively wide interpretations.

Included in the set concretes examined this year was one from Esperance from which the topping had lifted. Mineralogical examination of this concrete showed the presence of pyrite in the aggregate. This pyrite was shown to be a form unreactive to lime water. The failure of this concrete could not be attributed to the sulphide and the cause of failure may well have been not in in evidence in the samples submitted.

An examination was made of a group of sixteen samples taken as bore cores from a large mass of concrete laid more than 70 years ago. These samples were examined mineralogically as well as chemically and the significant properties of ignition loss and extractable silica were determined on specimens of the two types of aggregate separated from the samples. By making a number of reasonable assumptions it was possible to arrive at figures for the cement content of the original mix. This varied from 12 per cent to 18 per cent over the 16 samples. The pattern of sampling showed a decreasing leaching of lime with increased depth of sampling. The minimum lime leached out was 23 per cent of the original lime content, and the maximum 48 per cent.

Further samples were received this year of segments of septic tanks, which had deteriorated in service. These were submitted by the Public Health Department in a very weak and friable condition. The original mix was shown to be 6 parts of sand to one part of cement.

Aggregates.—Aggregates for concrete were examined for contractors engaged in producing large quantities of concrete, for contractors building at localities away from accepted sources of aggregate, (including the U.S. Navy establishment at the North West Cape) and for the Public Works Department.

Examination was mostly for deleterious materials and for potential alkali reactivity (P.A.R.).

The largest submission of aggregate samples came from manufacturers of premixed concrete, the U.S. Navy and the Public Works Department.

Aggregate collection.—The process of recording the results of accelerated chemical testing for aggregate reactivity to cement alkalis (P.A.R.), which was commenced in 1959, was continued this year and the Departmental collection of tested aggregates was increased from 52 at the close of 1964 to 69.

Of the seventeen aggregates added to the collection one only was classed as potentially reactive. This sample from Koolyanobbing consisted mainly of quartz with limonite and hematite, with some chalcedony and opal.

Four samples of milky white quartz examined for a private contractor gave results which were neither decisively reactive nor non reactive. These were later tested for mortar bar expansion and were classed as innocuous.

The remaining 12 aggregates classified by the P.A.R. test as innocuous, included:

(1) a fine grained banded quartz, pieces of hematite and a little secondary quartz, from vicinity of Port Hedland;
(2) a dolomite from the same locality;
(3) quartz, feldspar and goethite, locality not revealed;
(4) pyroxene, feldspar, epidote and a little calcite, locality not revealed;
(5) a fine grained chert containing quartz and chalcedony stained with iron oxides from Mt. Goldsworthy;
(6) quartzite from Bridgetown;
(7) crushed quartz, feldspar and hornblende from Westonia;
(8) sand from Brown's Range, 3 miles from Carnarvon;
(9) granite from Merredin;
(10) fine grained calcite from Rough Range.

Many other aggregates were tested for P.A.R., which were not included in the collection because they closely resembled aggregates already represented.

Light weight aggregate.—One aggregate tested for P.A.R. as part of a project by the Engineering Chemistry Division was an artificial light weight aggregate. The result of the test indicated that the material was potentially reactive (Rc 84, Sc 307)) but attention is drawn to the fact that the A.S.T.M. test for P.A.R. is not considered applicable to light weight aggregates and figures derived from this test should be treated with reservation. A commercial light weight aggregate was examined at the same time and classified a non-reactive (Rc 87, Sc 78).

Supporting the rapid chemical tests (P.A.R.) mortar bar tests were concluded on five aggregates reported on in 1964 and five further aggregates were tested. Mortar bar tests measure the expansion of test bars of concrete made and stored by standard procedures.

The tests commenced in 1964 on five river gravels for the Ashburton River bridge at Nanutarra, were discontinued after six months because no movement in the bars was apparent.

Similarly two milky white quartz aggregates showed no expansion of mortar bars prepared with high alkali cement, although the accelerated chemical test for P.A.R. had indicated a borderline result between reactivity and non-reactivity.

A Departmental investigation was conducted into the effect of different cements on the mortar bar expansion using a known aggregate of milky white quartz. It was concluded that with this type of aggregate the difference in cement alkalinity between 0.55 per cent Na_2O and 0.83 per cent Na_2O is of no significance with respect to cement: aggregate reaction.

One sample of efflorescence which built up rapidly on concrete during a wall section pour was examined. The sample was collected from the form exterior and was found to be predominantly calcite. The elements present in the water free acid soluble portion were determined with the result that they could be combined together to represent material of the following composition.

	per cent
$CaCO_3$	75
$CaSO_4$	10
$MgSO_4$	1
Na_2SO_4	5
NaCl	2
KCl	7

In addition to aggregates examined this year information was provided to the public on aggregate previously examined.

Sands.—Of the 18 samples of sand submitted for test for suitability for use in concrete, two only failed to conform to the Australian Standard. In both instances the failure was due to excess organic material. Four further samples were examined this year to determine whether the nature of the organic coating on certain sands was hydrophyllic or hydrophobic. Work reported in the 1964 Report had suggested that the nature of organic coating might be related to air entrainment observed in use.

Cement.—A local cement was analysed and found to conform in chemical composition to the specification given for type A Portland cement in Australian Standard A2—1953. The specific surface of this cement as measured by the air permeability method was 3,000 sq. cm per g.

Pozzolans and Fly Ashes.—A fly ash required for use in concrete was examined to determine if its properties conformed to those suggested by the 1962 Proceedings of the American Society for Testing Materials.

Chemical analyses for SiO_2, Fe_2O_3, CaO, MgO, Al_2O_3, SO_4, and ignition loss were made together with determination of percentage retained on a 325 mesh screen, specific gravity and specific surface.

5. Building materials (other than cement and concrete).—Three specimens of sandstone from Donnybrook were examined for comparison with other building stones. The results are summarised below.

	1	2	3
Bulk density lb./c.ft.	138	146	152
Porosity (per cent water absorbed)	7.4	5.5	5.7
Absorption rate (a)	8.6	1.8	2.0
(cubic in./sq. ft./hr.)	8.2	1.4	1.4

(a) under a head of 1 in. water; two readings, one each on two faces at right angles to each other.

Brick samples exhibiting a white to yellowish scum were examined together with unburned samples of clay and bore water used. The identity of the scum was not definitely established but both clay and water had a high content of soluble salts including sulphates. A scheme of investigation to decide if water, clay or both were responsible for the scum, was suggested to the producer, assuming the firing conditions were optimum. The established method of burning sulphate bearing clays was advised, as was the practice in some works of "fixing" sulphur with barium salts.

A brown stain on mortar associated with brown manganese bricks was shown to contain manganese, as did water flushings of bricks which had been washed one hour previously with 1:10 hydrochloric acid. The movement of soluble manganese is an ever present threat to mortar in the vicinity. Procedures which may assist in controlling this staining include mechanical removal of excess mortar and painting of surface with a silicone type protective film.

Two samples of material labelled calcium silicate were analysed for comparison with earlier samples, in an investigation of the cause of concrete blocks swelling to oversize. No significant chemical trend was apparent in the figures and it was concluded that the magnitude of differences in the analyses were not sufficient to indicate the relative usefulness of the materials.

A white powder said to be material for spray plastering of cement rendered walls was found to consist of crushed granite and calcite in the size range 10 to 30 mesh, with finely divided hydrated lime and approximately six per cent of white Portland type cement.

A zinc chimney tray as used by some builders in lieu of "4 lb" lead trays specified by the State Housing Commission was examined together with samples of mortar and chimney tars. The relative chemical resistance of both types of tray in the proposed environment were discussed but the most significant factor appears to be that the zinc tray was less than ⅓ of the thickness of the lead.

Materials examined for an operating brickworks were fire bricks, clay from stock pile and pit sand. Chemical analyses were made of the clay and sand, together with mineralogical examination. The bricks were examined mineralogically in conjunction with work of the Fuel Technology Division.

6. Miscellaneous Identifications.—Parts of an explosive golf ball of Japanese origin were examined in conjunction with the Food and Drug Division. Constituents identified were red lead, silicon and a minor amount of red phosphorus, with a "striker mechanism" of coarse rock grains, mainly chert.

Dark specks found in a drum of ammonium nitrate were found to be artificial equivalents of magnetite and hydrated iron oxides, probably residue from previous contents of the drum rather than a corrosion product of the drum.

A pipe joint compound, the use of which had been questioned in connection with contamination of domestic water supplies, was examined and found to be essentially a type of Sorrel (magnesia) cement. A water extract of the set cement contained no harmful concentrations of salts.

An examination was made of a stainless steel welding flux no longer available in Australia and found in practice to be superior to local fluxes. X-ray and chemical analysis suggests the following constituents: potassium tetraborate $K_2B_4O_7.5H_2O$, 60-65 per cent; potassium fluoborate, 35 per cent; lithium borate, 1 per cent; with a fluorescent acetone soluble dye.

The constituents of a mud which had been used for drilling an oil well were identified as various rock fragments, baryte and a clay fraction containing bentonite, illite and kaolinite. No direct evidence of Portland type cement was found.

A sludge from a transformer operating at a country water storage was found to be largely metallic iron flakes covered and accompanied by hydrous iron oxides. Also associated with this was organic material in which formic acid derivatives were identified probably from break down of urea-formaldehyde resins.

A zinc coating material was submitted to establish that it complied with a U.S. Navy specification. The requirements were that the pigment should be zinc and that the vehicle should be inorganic. Both requirements were met.

In the investigation by the Police Department of a case of suspected wilful damage, the sediments from the oil filter and sump of a tractor were examined. From the sump the sediment consisted of rounded quartz and limestone grains with a little metal oxide. The filter contained also some fine metal fragments. No silicon carbide, aluminium oxide or other artificial abrasives were present.

Two samples of an ash accumulation at the bottom of a Kununarra cotton-gin incinerator were examined as part of an investigation by the Fuel Technology Division into efficient burning in the incinerator. The ash assayed as follows. the second sample had been "watered" in the incinerator.

	per cent	
K_2O	23.2	18.1
SiO_2	15.2	10.5
Loss on ignition	35.5	30.6

Foreign material removed by Department of Civil Aviation from an engine of a light aircraft consisted of rounded quartz grains coated with a tenacious organic char. A few grains were coated with a white fused material consistent in appearance with heat treated clay. It was concluded that the material derived more probably from the moulding sand of the engine casting than from accidental contamination in service.

Mineral fragments from the carburettor of another aeroplane proved to be amorphous silica with the characteristics of commercial silica gel.

PHYSICS AND PYROMETRY SECTION.

The work of this section is described under the headings Pyrometry, Thermal Methods and X-ray Methods.

Pyrometry

There was a marked decrease in the work received, the total requirements being the calibration of an optical pyrometer to 1,200°C, and the calibration of seven mercury in glass thermometers to 100°C.

Thermal Methods

The differential thermal apparatus is in regular use as a means of confirming mineral diagnoses difficult to interpret by other means alone. In what follows this is made apparent by the frequent reference to both X-ray powder diffraction and differential thermal analysis.

The standard conditions of operation are that 0.3 gm. of finely powdered sample, diluted and thoroughly mixed with 1 gm. of fine alumina to overcome base line drift due to thermal conductivity, are heated at 20°C per minute in an internally wound furnace, and the sample temperature is compared with the temperature of an inert reference (alumina). The resultant record clearly indicates the temperatures at which chemical and physical reactions occur in the sample. It is hoped at some future time to amplify this equipment by means of a thermobalance, to more completely characterise such reactions.

Some examples of the type of problem studied primarily by the differential thermal method follow.

(1) Phosphate Minerals.

(a) Brushites.—Supplementary work to elucidate the nature of the mineral brushite, first occurrence in Western Australian cave deposits, see Mineral Division report, was carried out by thermal analysis. The X-ray powder data of these Western Australian brushites, and others, are nearly identical with those of artificial $CaHPO_4.2H_2O$ but have some differences from those of the natural brushite described by Murray and Dietrich (Am. Min. 41, 616, 1956).

Differential thermograms of the Western Australian samples resemble those of Murray and Dietrich and the artificial compound but have extra endotherms at 920°C and 230-250°C as shown in one case in Figure 4, curves (i) and (ii). A partial chemical analysis of this sample, given in Table 40 under the heading "W.A. Brushite" suggests that it could be explained by a physical mixture of approximately 22 per cent gypsum and 78 per cent brushite. A differential thermogram of such a mixture, curve (v) Figure 4, shows endotherms at 930°C and 1,050°C but none between 200 and 300°C. From this it appears that solid state reactions can occur between the phosphate and sulphate minerals, but that the Western Australian brushite thermograms cannot be fully explained in his way.

(b) Ardealites.—The X-ray powder patterns of two of the samples from these cave deposits resemble those of brushite and gypsum, but contain strong lines not identifiable on the basis of a mixture of the two, and no plausible third component was found in the X-ray Powder Diffraction Data File.

Table 40.

Partial Chemical Analyses.

—	Brushite $CaHPO_4.2H_2O$	W.A. brushite	? Ardealite	Ardealite $CaHPO_4.CaSO_4.4H_2O$
	per cent	per cent	per cent	per cent
CaO	32·6	32·6*	31·9	32·6
P_2O_5	41·3	30·2	21·3	20·7
SO_3	....	9·7	23·2	23·2
H_2O	26·1	....	....	23·5
Ignition loss to 700° C.	....	27·5	25·0	....
	100·0	100·0	101·4	100·0
Ignition loss between 700° C. and 1,200° C.	....	11·2	20·4	....

* By difference.

Table 41.

Thermal Products Identified by X-ray Powder Diffraction.

Thermal Treatment	Domica brushite ; W.A. brushite	? Ardealite	Gypsum
Raw	Brushite $CaHPO_4.2H_2O$	" Brushite "	Gypsum $CaSO_4.2H_2O$
130° C/2 hr.	Monetite $CaHPO_4$ + brushite	" Brushite " + trace " hemihydrate "	—
300° C/1 hr.	Monetite *	" Hemihydrate "	Anhydrite $CaSO_4$ + some hemihydrate $CaSO_4.\frac{1}{2}H_2O$
600° C/½ hr.	B3 + trace monetite	" Hemihydrate " + trace " anhydrite "	Anhydrite
800° C/½ hr.	B3	" Anhydrite "	Anhydrite
1,000° C/½ hr.	Calc. pyrophosphate β–$Ca_2P_2O_7$	Whitlockite β–$Ca_3(PO_4)_2$	Anhydrite
1,100° C/½ hr.	β–$Ca_2P_2O_7$	Whitlockite	Anhydrite

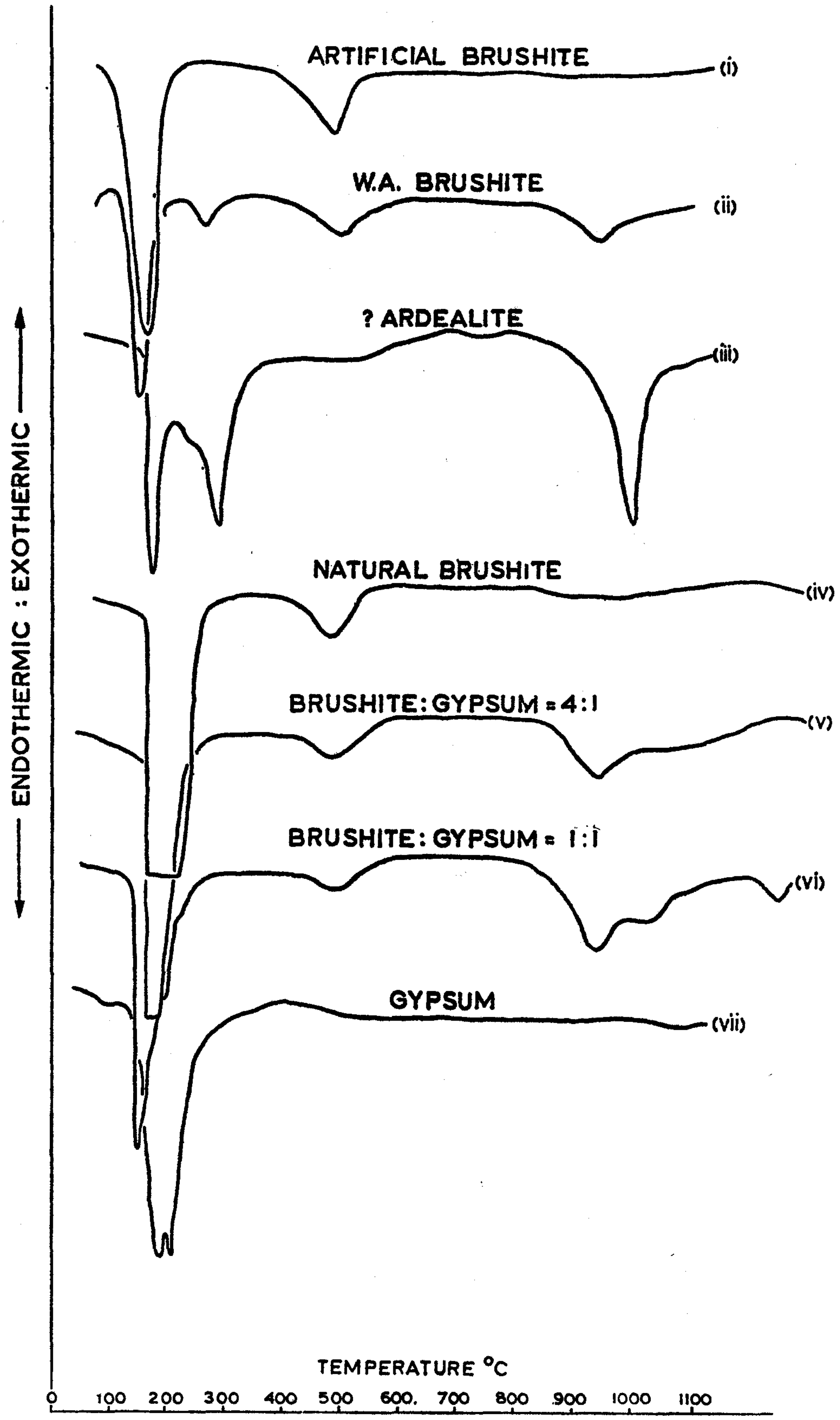
* See Am. Min. 41, 616, 1956.

Thermal analysis of one of these unknowns, see Figure 4 (iii), and X-ray patterns taken of the thermal products of the reactions so indicated, see Table 41, together with a partial chemical analysis, Table 40, all indicate that this sample is a mixed phosphate/sulphate. A literature search on this basis disclosed X-ray powder patterns (F. Halla Z. Krist. 80, 349, 1931) of ardealite $CaHPO_4.CaSO_4.4H_2O$ which closely resemble the pattern of this sample. Comparison of thermograms (vi) and (iii) in Figure 4, and the X-ray powder pattern, support the contention that this is not a physical mixture of brushite and gypsum, but is in fact another occurrence of the rare mineral ardealite, previously reported only from Cioclovina Cave in Transylvania and on old bones in a cemetary in Olomouc, Russia (Dana Vol. II). Further work is being done to separate crystals of this mineral, and a more complete report will be published elsewhere.

(2) Stilpnomelane. In 1963 a stilpnomelane had been identified in a Geological Survey sample of banded ironstone from Wittenoom. A more coarsely crystalline sample of the same mineral was subsequently submitted for study. X-ray powder diffraction patterns of this sample showed it to have close resemblance to those published by Mather and Atherton (Nature 207, 971, 1965) and Gruner, (Am. Min. 22, 912, 1937).

Differential thermal analysis was carried out to assist in calculating a formula from the chemical analysis, Table 42. The thermogram, by comparison with Nagy's curves (Am. Min. 39, 949, 1954) lies between those of ekmannite and stilpnomelane, Figure 5.

The endotherm at 150°C is somewhat high in temperature to be due to purely absorbed water; thus there is either some loss of lattice OH at this temperature or some of the water is interlamellar.



DIFFERENTIAL THERMOGRAMS

FIGURE 4

The formula derived from the chemical analysis is:

$(OH)_{10.2}(Na_{0.3}K_{0.4})(Fe^{2+}_{3.8}\ {}^{3+}_{0.4}Mg_{2.0}Mn_{0.02}Ti_{0.04}P_{0.1}Al_{1.0}Si_{0.2})(Si_8)\ O_{19.8}$

The above information together with X-ray powder patterns of the stilpnomelane and its thermal products will be published more fully elsewhere.

(3) Chrysocolla/Natroalunite. A porous mineral specimen of apparent density 0.5 from the Roebourne area gave weak X-ray diffraction pattern with much background. The measureable lines indicated an alunite as the crystalline phase and the possibility of chrysocolla backed by the high copper content of 21 per cent. The alunite on further chemical and X-ray work was resolved as natroalunite. The background is possibly due to allophane or amorphous silica. A differential thermogram, shown at top in Figure 6, did not completely resemble either chrysocolla or natroalunite, but it was theorised that solid state interaction of these two above 550°C might explain the absence of chrysocolla's exotherm at 720°C. The thermogram of a mixture of 70 per cent chrysocolla and 30 per cent natroalunite, shown second from top in Figure 6, agrees closely with that of the sample 696/65. The relative composition calculated from chemical analysis, neglecting other constituents, was 80 per cent chrysocolla and 20 per cent natroalunite. The thermograms of chrysocolla and natroalunite reproduced in Figure 6 are not drawn to the same scale. Further detail on this solid state reaction and its implications will be published elsewhere.

Table 42.
Chemical Analysis.

	per cent
SiO_2	45.54
Al_2O_3	4.75
TiO_2	0.26
Fe_2O_3	2.90
FeO	25.38
MnO	0.13
MgO	7.75
CaO	0.04
K_2O	1.96
Na_2O	0.82
H_2O^+	8.46
H_2O^-	1.56
P_2O_5	0.44
CO_2	0.28
	100.27

Note: CO_2 was presumed due to Mg, Ca carbonate, and was eliminated.

X-ray Methods.

Increase in the use of the powder method as a means of rapid routine mineral identification has at times caused some congestion, as three mineralogists and one physicist have had to make use of the one camera. To ease this situation a new powder diffraction camera of 5.75 cm. diameter has been obtained.

Some examples of the type of problem handled primarily by means of X-ray powder diffraction are given below.

(1) Brockman Shales.— Exploratory drilling in the Brockman Iron Formation in the Wittenoom-Yampire area has shown that a third of the thickness of the Brockman consists of shale (G. S. Annual Report 1964). Since a close study of the shale is considered essential for a proper understanding of the formation as a whole, a representative collection was sent from Geological Survey Branch to these Laboratories as a pilot exploration of the mineral content of these rocks.

Small portions of each sample were pulverised by diamond mortar and the less than twenty micron equivalent spherical diameter fractions separated by water elutriation using calgon as dispersing agent. These fractions were examined by the standard X-ray diffraction procedure for sheet silicate minerals. Differential thermal analysis curves were also obtained for most of these fractions to aid in identifying and estimating pyrite, carbonates and carbonaceous matter.

The most common mineral throughout the shales was stilpnomelane, and the associated sheet silicate minerals were chlorite, mica and montmorillonoid. Other minerals present were felspars, pyrite marcasite, Fe and Mg carbonates and goethite. The results are expressed in the form of a phase diagram in Figure 7, compiled in a manner similar to standard ACF diagrams for three or four components. Thus for example the significance of the point marked (a) on the phase diagram is that the sample consisted of approximately equal amounts of stilpnomelane and chlorite, with appreciable carbonate also present; the point marked (b) similarly implies that the mineral assemblage was approximately equal amounts of stilpnomelane montmorillonoid and chlorite, with appreciable felspar present.

Conclusions to be immediately drawn from such a display, which would not immediately be obvious from tabulated results, are that (i) stilpnomelane occurs alone or as the predominant constituent in the majority of cases.

(ii) The pairs stilpnomelane-mica and stilpnomelane-chlorite occur, but not stilpnomelane-montmorillonoid, although the groups stilpnomelane-chlorite-montmorillonoid and stilpnomelane-chlorite-mica are found.

The usefulness of this diagram is limited by the small number of analyses made, and by the impreciseness of the mineral identification i.e. distinction should be made between muscovite and biotite micas etc.

(2) Ferritungstite/Stibiconite. Thin films of a powdery yellow mineral associated with scheelite from the Marble Bar area were identified by X-ray and chemical data as ferritungstite.

The mineral has seldom been reported in the literature but Simpson (Vol. 2 Minerals of Western Australia) records ferritungstite from nine localities in Western Australia, the identifications being based on physical and chemical data. One specimen was subsequently X-rayed and confirmed as ferritungstite.

Richter et al (Am. Min. 42, 83, 1957) claimed that the original description by Schaller (Am. Jour. Sci. (1911) 4th Ser. 32, 161-162) was in error. and proposed a new formula $Ca_2Fe_2^{2+}Fe_2^{3+}(WO_4)_7\ 9H_2O$. They indexed their powder data on a tetragonal cell with $a_0 = 10.28$ Å and $c_0 = 7.28$ Å with $z = 1$. Nevertheless they were unable to explain the anomalous occurrence of ferrous iron in a mineral formed in an oxidising environment and the odd number of WO_4 groups in a supposedly tetragonal unit cell.

During the present investigation it was found that powder patterns of ferritungstite could not be distinguished from those of stibiconite, a cubic mineral with the pyrochlore structure ($a_0 = 10.26$ —10.28Å). Examination of the powder data of Richter et al indicated that their data could be indexed on a face centred cubic cell with $a_0 = 10.28$ Å, and this was confirmed by the discovery that Van Tassel (Bul. Soc. Belge Geol. 70, 376-399, 1961) with single crystal work had proposed a face centred cubic cell with $a = 10.22 — 31$ Å and $z = 4$ for the mineral.

His analyses indicated the absence of ferrous iron and also little or no calcium, but did include aluminium.

A more recent paper by Burnol et al (Bull. Soc. franc. Miner Crist. 87, 374-5, 1964) also showed the absence of ferrous iron, and by electron probe analysis the absence of aluminium. The position of calcium was less certain but these authors considered it to be due to contaminants.

Work on a Simpson Collection specimen (S 228) also indicated the absence of ferrous iron, but no positive evidence for calcium could be obtained due to the presence of scheelite in the sample.

The consensus thus appears to be that ferritungstite is a hydrated ferric tungstate in which calcium and aluminium if present, play a subordinate role. The formula is still uncertain but will probably approximate to the pyrochlore group formula $X_y\ Y_x\ (O,OH,H_2O)_7$.

The problems involved in this work are being further investigated and the final results will be published elsewhere.

(3) New Mineral. A routine re-examination, by X-ray diffraction, of samples held in the Mineral Division collections has disclosed a pure mineral unidentifiable by the X-ray Powder Data File. The mineral was shown chemically to be an aluminium silicate antimonate tantalate. A thorough search disclosed nothing resembling this reported in the literature to date. On this basis it was considered to be a new mineral and therefore of value to publish a complete mineral description.

To this end a series of Weissenberg single crystal exposures was commenced in June. The description, to be published elsewhere, will also contain the space group and a powder pattern indexed by the accurate unit cell parameters gained from Weissenberg exposures. A complete structure analysis will follow later.

(4) Routine Mineral Identifications. In the normal course of mineral identifications carried out by these Laboratories considerable difficulty is caused by extremely fine grained components. In such cases the X-ray powder diffraction method can often shorten the procedure by a rapid identification, even in cases of mixtures. Some typical examples of this follow.

A commercial welding flux was separated into three fractions characterised by solubility in water. X-ray powder diffraction patterns showed the most soluble fraction to consist of hydrated potassium borates, while the least soluble fraction consisted of a mixture of potassium boron fluoride (KBF_4) and hydrated potassium borates. The water insoluble fraction (1 per cent) resembled a clay mineral and was considered to be an impurity.

An apothecaries mortar, a relic from a wreck supposed to be the "Gilt Dragon", was examined to identify the fine grained oxidation product, with only moderate success. A pale green powder was shown to contain copper, but the majority of the sample remained unidentifiable. Similarly a brown powder contained copper, cuprous oxide and a further unknown. Metal turnings from the unaltered metal resembled the pattern of copper but for a larger unit cell, and were shown chemically to contain lead and antimony also.

Fine grained bauxites from a new locality in the Kimberley District were shown to consist largely of gibbsite. The insoluble minor constituents were identified as mixtures of boehmite, corundum, anatase and quartz.

Two rare fine grained minerals from the Belvedere Gold Mine, Mt. McGrath were the copper arsenates cornwallite and conichalcite.

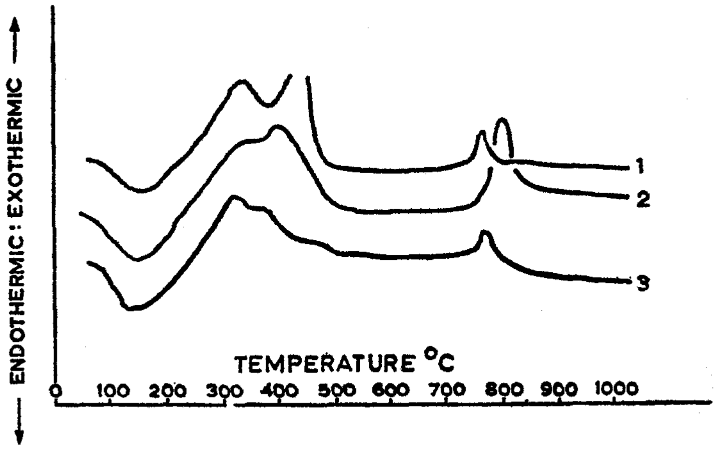
The rare bismuth vanadate pucherite, a secondary mineral, was identified in a sample from Menzies, a new locality for this mineral.

Air-borne dusts and sediments from a Swan Portland Cement Co. flue stack were shown chemically to contain much water soluble K, Cl and SO_4, with some Na, and much acid soluble Ca and CO_3 in the residue. The state of combination of these ions was demonstrated by X-ray powder diffraction, the compounds identified being KCl, K_2SO_4 and $CaCO_3$. The sodium present probably replaces some potassium in the sylvine. Acid insolubles were shown to be quartz.

Another example of determination of the state of combination was demonstrated by the analysis of two samples from an ammonium nitrate drum sent in by the Explosives Branch. The first, a black magnetic powder, was shown to be a mixture of magnetite $Fe_3O_4.\gamma Fe_2O_3.H_2O$ and $\alpha Fe_2O_3.H_2O$. Magnetite was confirmed chemically by the presence of much Fe^{2+}. The second sample, a brown non-magnetic powder, contained $\gamma Fe_2O_3.H_2O$ and $\alpha Fe_2O_3.H_2O$.

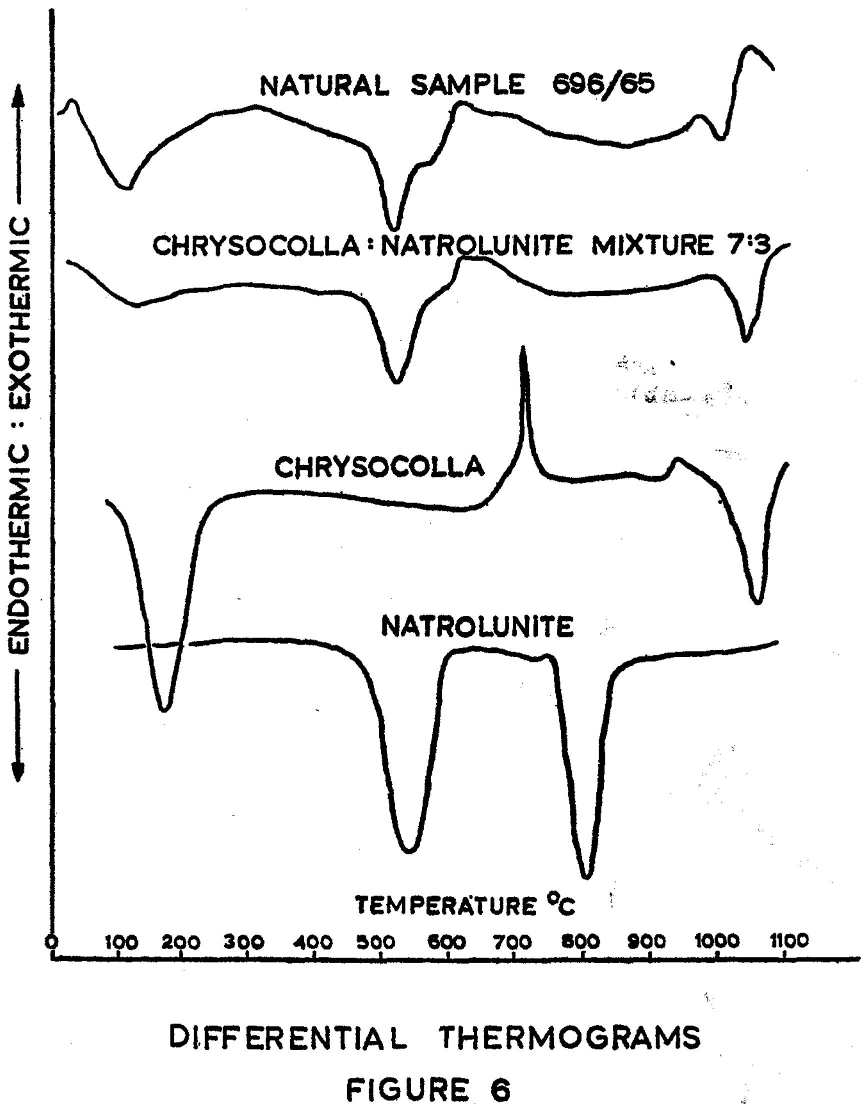
A corrosion product scale from an air conditioning condenser was received for supplementary work by X-ray diffraction. Powder patterns showed a resemblance to hisingerite and to a previously reported sample which was a water deposit formed by the action of heat and pressure in glass bottles containing tap water. However, the presence of 10 per cent Mg and only 1 per cent Fe in this case infers that the mineral is the magnesium analogue of the iron silicate hisingerite. On ignition, the crystaline products were enstatite ($MgO.SiO_2$) and α cristobalite.

This sample marks the second occurrence recorded in these Laboratories of the artificial formation of hisingerite as a corrosion product. Since this sample was much larger than the first recorded, separation into particle size fractions will be carried out for thermal analysis.

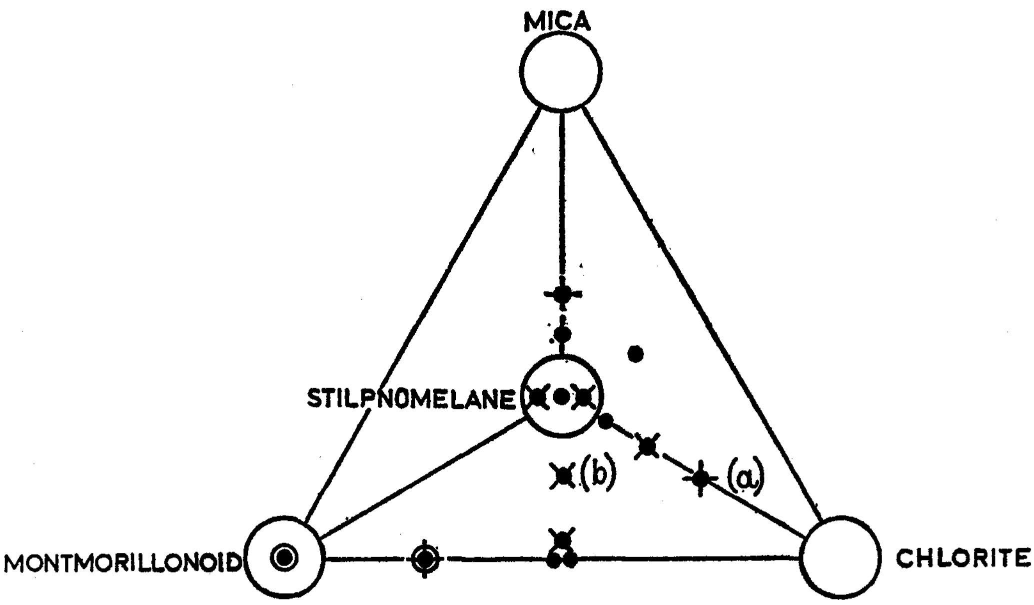


THERMOGRAM 1 : STILPNOMELANE (NAGY)
THERMOGRAM 2 : STILPNOMELANE (WITTENOOM W.A.)
THERMOGRAM 3 : EKMANNITE (NAGY)

DIFFERENTIAL THERMOGRAMS
FIGURE 5



DIFFERENTIAL THERMOGRAMS
FIGURE 6



● SAMPLE COMPOSITION EXPRESSED BY POSITION ON PHASE DIAGRAM

✕ FELSPAR PRESENT IN APPRECIABLE QUANTITY
-¦- Fe, or FeMg CARBONATE PRESENT IN APPRECIABLE QUANTITY
○ GOETHITE PRESENT IN APPRECIABLE QUANTITY
] ADDITIONAL INFORMATION ON SAMPLE COMPOSITION

PHASE DIAGRAM BASED ON MINERAL CONTENT
OF
HOMOGENEOUS SAMPLES CONTAINING STILPNOMELANE
FIGURE 7

CONTENTS

DIVISION VIII

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Annual Report of the Chief Inspector of Explosives for the Year 1965

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The Under Secretary for Mines:

For the information of the Hon. Minister for Mines, I am honoured to report on the functioning and scope of the Explosives Branch during 1965.

Staff.

Another year, the busiest on record, closed without promise of augmented staff. A changed pattern of work necessitating recurrent inspectional services, often at remote localities, so pressed the Branch's staff resources that on four occasions the Magazine Keeper at Woodman's Point Explosives Reserve, in his capacity of Sub-Inspector, was sent north to supervise shipping, storage and conveyance of explosives. He could ill be spared from his main duties, which naturally became more onerous in proportion to heavier throughput during 1965. As to the future, it must be emphasised that Dangerous Goods Regulations, when gazetted, will have to be shelved or at most implemented on a token scale unless the requisite inspectional and clerical assistance is provided and trained in advance.

Accommodation and Facilities

The situation at Head Office remained unchanged. Progress at Woodman's Point Explosives Reserve included completion of a new residence for the officer-in-charge and replacement of the old single-room guardhouse by a brick and tile building divided into an office, staff amenities room and storage space. Repair of the main road and gravelling of its extension to the three new magazines was undertaken. Works of a non-departmental nature comprised provision of improved access to several magazines, and a small office established by one of the importers. Another development was the clearing of a wide swathe parallel to the western boundary for temporary stacking of canned N.C.N. explosives. This solved an otherwise insurmountable storage problem—and incidentally provided the largest firebreak in the Area.

Importation of Explosives and Blasting Agents.

The State's supplies arrived by ship at approximate monthly intervals, supplemented by transcontinental railage to the Eastern Goldfields or further westward as decreed by local demand. Although as for years past Woodman's Point Explosives Reserve continued to receive the major tonnage, the practice of discharging explosives and blasting agent components at or near heavily consuming northerly localities gained considerable ground during 1965. Four shipments from abroad were thus treated at ports such as Hedland, Samson, Wyndham, Dampier and Geraldton, with calls at Woodman's Point if so scheduled on the outward or return voyage. Similar procedure, also applied to one consignment from Victoria, was intended for repetition but perforce abandoned on account of disaster—to be described later.

Negotiation with the Fremantle Port Authority resulted in the former 25 ton limit on bagged ammonium nitrate over Woodman's Point jetty being raised to 400 tons. Quantities allowable at inner harbor berths were brought into line with those applicable to steel drum encasement, provided seatainers were used under defined conditions. Credit must also be accorded the Harbor and Light Department as controllers of northerly ports for co-operation with the Explosives Branch in regulating dangerous goods shipping movements. An unprecedented instance came into being with development of Dampier which, by virtue of private ownership, lay outside F.P.A. and Harbor and Light jurisdiction. However, the situation was resolved to mutual satisfaction by acceptance of recognized safety standards.

Consequent upon closure and subsequent demolition of the old naval jetty south of the Quarantine Station, two small incoming shipments of explosive ordnance and one loading of over-age material for dumping at sea were handled at Woodman's Point Explosives Reserve jetty.

Outward-Bound Explosives by Ship.

Although no actual export took place except to the island phosphate rock industry, increased business in serving seismic survey vessels was recorded. As before, explosives for Yampi were taken aboard ship at Kwinana.

Authorised Explosives.

The following additions to the List of Authorised Explosives were effected:

Part A, Class 2, Nitrate Mixture.—
Molanal (ZZ).

Part B, Class 3, Nitro-Compound—

Division 1

- Ammonia Gelatine Dynamite Kiri (ZZ).
- Hi-cap (ZZ).
- Semi-gelatine Dynamite Katsura (ZZ).
- Vibrogel 3 (ZZ).
- Gelamite D (ZZ).
- Anzite (ZZ).
- Aquamex (ZZ).
- Du Pont Gelatine Primer 80 per cent. (ZZ).

Division 2

- Titan Booster 25 (ZZ).
- Vibronite S, Primer (ZZ).
- Vibronite S (ZZ).
- Vibronite B (ZZ).
- Vibronite B-1 (ZZ).

Review of New Explosives.

Prior to their authorisation, the above varieties were encountered in W.A. only as samples or small trial lots. Those containing nitroglycerin proved on analysis to be comparable with corresponding established lines. Anzite, however, contained a new absorbent, whilst Aquamex could be described as an N.G. slurry sealed into polythene tubes protected and rigidified by cardboard cylinders. Because of its non-self-explosive components, Molanal was in effect a factory-made blasting agent. Though more complicated than the simple AN-FO compositions, it would similarly have been adaptable to mixing at or near the point of use, but the manufacturers preferred professional preparation. Basically, a small mixing plant was intended for local operation as a prelude to installing additional units in heavily-consuming districts. The Vibronites listed in Division 2 fall within the nitro-carbo-nitrate category; these classes of explosives and their mounting importance in seismic and other underwater blasting were described in last year's report.

Application for authorisation of a Japanese non-N.G. explosive named Carlit, though originally recommended, was withdrawn following a re-appraisal of properties. Commendable features such as performance, freedom from exudation and low hygroscopicity were overshadowed by proneness to deflagration on ignition and an impact sensitivity deemed potentially dangerous during tamping by users accustomed to other explosives. The possibility of fire or premature explosion could not be ignored. The unusual characteristics of Carlit appeared linked with the presence of ammonium perchlorate—a component described by the U.S. Bureau of Mines as dangerous and not permissible in explosives submitted for official recognition.

About five tons of Kozumaite, unauthorised but imported under permit as provided by Regulations, was used successfully by Japanese technologists in harbor deepening trials at Port Hedland. This explosive also contained ammonium perchlorate in small proportion, but as it was marketed blockwise in shaped charge fashion, sealed in plastic and metal-strapped for lowering, no apprehension was felt.

In the blasting agent field, the straight ammonium nitrate-oil mixtures continued to hold their place despite interest shown in adaptations such as slurries and surfactant preparations. Of the former type, a premixed preparation of aluminium, sulphur, carbonaceous material and thickener for incorporation with water and oxidisers before use was examined departmentally with promising results, but no reports of full-scale trials came to notice. ANFO compositions containing surface-active agents, or surfactants, first demonstrated at Kalgoorlie in August, 1964, were recently under investigation by two large mining companies. Some such compositions failed through break-down of the prill to an insensitive powder, with evolution of ammonia probably ascribable to alkalinity. However, these early setbacks will assuredly be overcome, and it is interesting to note that a ready-packaged surface activated explosive was accepted for authorisation in South Australia under the name of Quilox.

Accident to Shipment of Explosives.

The State's worst disaster to explosives in transit occurred when M.V. Blythe Star grounded on the beach about 100 yards south of Woodman's Point jetty. With a cargo of 13,109 fiberboard cases of explosives, of which about one-third was intended for later discharge at Dampier, the vessel arrived on June 29 in poor weather conditions which so deteriorated next morning that preparation was hastily made to seek shelter in the lee of Garden Island. At the moment of casting off, the engine failed to start and the prevailing gale-like winds broadsided the vessel onto the beach, where it settled with a seaward list of 17 deg.

So intense was the storm that the Blythe Star was at times completely obscured to view from observers on the jetty. Suspicions of breached hatch covers and inundation of the hold were duly confirmed by a boarding party. On July 1, still under difficult conditions, the detonator magazine was hauled ashore from its high deck position by an aerial ropeway. This potential hazard removed, salvage crews were able to concentrate on getting out the explosives to confer greater buoyancy on the hull and minimize contamination and danger expected from the progressively deteriorating cargo. With pumping in operation to reduce flood-water level and carry away probable exudate, cases were lifted manually and slid by chute for stacking on the beach. Later a crawler-type crane expedited the process, and a front end loader proved serviceable in relocating earlier stacks beyond wave and and tide action. Work continued by night under floodlight, and the holds were emptied on July 8.

Except for about half the 350 cases of explosives recovered from above water level at the port side of the hold, the entire cargo less detonators was deemed unfit for storage, transportation and use. Certain local interests disagreed with the decision which, however, was vindicated by three technical experts from the Nobel factory in Melbourne. Then came a major disposal job. To lessen immediate danger, scraps of explosive on the beach or oozing from disintegrated cases were collected and burnt. As this tedious method of destruction accounted for an insignificant proportion of the condemned material, dumping in a defined deepwater area beyond Rottnest appeared the only solution. Of the few suitable craft available for such an undertaking, a capacious hopper barge was selected. Every explosives package, some in a difficulty-handleable mush by this time, had to be taken from beach to rail truck and thence to the jetty head. Prior to their transfer many cases were placed in polythene bags, and the same protective treatment was extended as necessary to others when further deterioration occurred. By means of a chute kept wet to reduce friction and sparking tendencies, the packages were slid individually into the barge's water-filled cargo compartments. Final disposal took place without untoward incident.

Though not within the scope of this report to describe shipping aspects, including the Blythe Star's refloating, brief reference must be made to clean-up and decontamination. The ship itself presented no particular problem because after slipping for inspection and repair, flooring and wooden hold lining was replaced. At the Reserve, hundreds of discarded cases and wrappings were burnt. During the various movements involving explosives, wooden surfaces such as jetty decking and rail van interiors were as far as practicable protected by impervious sheeting. As an extra precaution, however, chemical treatment where necessary and hosing with high pressure jets found wide application.

Accident—Road Transport of Explosives.

In the Eneabba district on March 4th, a seismic shooting truck laden with 2 tons of ammonium nitrate prill, 2.2 tons of high explosive and 192 electric detonators was completely destroyed by fire. Erratic engine performance and failure were followed by a burst of flame under the wooden tray behind the driving compartment. A 2 lb. CO_2 extinguisher proved ineffective, and the intended use of a second one was abandoned as the fire gained hold. The high explosive burnt without detonation, and molten ammonium nitrate poured over the ground. Later investigation revealed that the detonators had exploded inside their wood-lined steel mazazine, but were thereby so well protected that no communication to the main load occurred. Though the precise cause of fire could not be determined, suspicion fell on the electrical and exhaust systems, for both of which modification in existing and future units was suggested. Recommendations were made for more adequate fire extinguishing equipment of the foam or dry-powder type.

Destruction of Explosives

Routine burning of unwanted samples, police exhibits and privately-owned explosives proceeded as usual. Where unknown lines were encountered, properties and chemical composition were usually determined and have proved serviceable in assessing hazards or sometimes tracing the origin of illegal manufacture. A prototype blasting agent submitted five years ago consisted of urea and aluminium, both of which have assumed recent importance as components of metallized slurries and similar preparations.

The Blythe Star explosives disposal presented a problem in the instance of 400,000 ft. of detonating fuse, known in advance to float whether encased or as unreeled strand. As the recommended destruction by explosion proved impracticable at the Reserve, experimental firing in a disused quarry near Toodyay was undertaken, and a plan formulated for dealing with the remainder. Though not yet completed, these investigations yielded interesting incidental information on sensitivity and spacing to prevent sympathetic detonation.

Government Explosives Reserves

A difficult situation arose at Port Hedland because of encroaching protected works on the old small area containing one magazine. Neither of two likely alternative blocks in view, one with seaboard access, was available. Urgency of providing suitable land may be gauged from lodgment of two firm applications and several inquiries for leasehold magazine sites before the year closed.

Woodman's Point Explosives Reserve reached a stage where rational use of existing facilities called for consideration. If, with due allowance for occasional surge loadings, stocks were consolidated rather than distributed among all magazines, the same area could hold a substantially greater tonnage. This plan was applied in principle at Bantry Bay Reserve, N.S.W., by allocating space in the magazines, all State-owned, to the several importers according to reasonable requirement instead of some stipulated higher amount which might never be attained.

The Government magazines at Woodman's Point (2 × 30 tons + detonator storage) could well be augmented by additional buildings if the expected demand for more accommodation continues. On the basis of a weekly fee per unit of storage, these magazines have long been used for explosives and seasonal-demand goods such as fireworks. Rarely empty, they may be overtaxed to receive 50 tons of Japanese explosive scheduled for arrival in March, 1966.

The Reserve's internal railage system degraded over the years to a stage where W.A.G.R. engineers recently advised part-relaying and extensive repair. Additionally, a few chains' extension to several existing tracks would open up three good sites for magazines of aggregate capacity 120 to 150 tons. All these works should be considered in conjunction with the standard gauge project which, along with present facilities, will ultimately serve the jetty and storage points for both inward and outward explosives conveyance.

Explosives Storage and Handling—S.A.A. Code

Four meetings of the Standards Association of Australia Committee in eastern capital cities served throughly to revise and modernise the Code, to be published in 1966. Mr. Greaves, representing the Explosives Branch, attended and maintained close touch throughout with the W.A. Chamber of Mines on relevant matters. Of particular interest was the section dealing with ammonium nitrate blasting agents, a field in which W.A. has had considerable experience and was able substantially to contribute to the Committee's work.

Inspection of Explosives

The established plan of inspecting all explosives on arrival and checking at least annually on their storage, quality and handling was carried out as far as possible, and most licensed explosives sellers were visited. Particular attention accorded shipments at northerly ports and to new areas such as Pilbara and Hamersley of heavy present or expected future explosives consumption revealed various irregular practices committed either unwittingly or as makeshift. A commendable response to departmental advice generally followed, but despite progress, provision of adequate and secure magazine storage proved unattainable in some cases.

Except for the ruined Blythe Star cargo in June and a few minor instances of deterioration by wetting, all conventional explosives entering the State complied with definition, physical specification and stability requirements. Nitrocarbonitrates and other Class 3 Division 2 explosives were also found satisfactory. Samples representing large importations of blasting-agent grade ammonium nitrate from N.S.W., U.S.A. and Japan were of good oil absorptive capacity and lower in organic matter than the maximum permissible 0.05% The only rejection was part of an American shipment packaged in bags failing to provide proper protection against moisture ingress.

Explosives and Dangerous Goods Act, 1961 and Regulations

The draft Flammable Liquids Regulations, examined during the year by the Petroleum Marketing Engineers' Advisory Committee, brought forth numerous suggestions and comments. Mr. G. A. Greaves, on departmental business in Melbourne last May, met the Chairman and several committeemen in discussions which clarified the situation and served to resolve many issues. The Australian Paint Manufacturers' Federation, also vitally interested, appointed a special representative to examine the draft. A major point arising from this survey, already acted upon here by preparation of a draft Order in Council, was the suggestion for exemption from regulation of flammable liquids in containers not exceeding one gallon capacity. Thus many complications should be avoided. Those parts of the older regulations referring to service station filling and bottling rooms for retail trade were also expunged as being outside the Act's scope. The Chief Inspector of Factories agreed in principle with these working places being controlled under the Factories and Shops Act.

A study of flammable liquids storage in country towns revealed generally unsatisfactory and even dangerous practices. Backyard drum depots, sometimes alongside dwellings and workshops, and small tank installations for direct supply of motor fuel to consumers were commonplace. Guidance in such matters was sought from the Explosives Branch by Shire Councils, some of which encountered difficulties through lack of experience and authority for control.

By late 1965, another draft incorporating all that was learnt from several years' work was prepared for circulation and comment. Little further amendment should be required before gazettal—but even then, unless early action toward adequate staff resources is taken, as previously mentioned, two years may elapse before the Regulations become effectively applied.

Investigation of Fire and Explosion.

The Branch continued to receive inquiries, mainly from the Police Department, concerning possible causes of fire in industrial premises. Results of these investigations were reported and evidence given in the Coroner's court where necessary. Generally the origin and precise point of ignition were hard to determine, but much was learned from questioning of operatives and a search of the burnt-out building. Such findings as vehicles cluttered under the one roof with welding equipment, drummed flammable liquids, chemicals and an array of general merchandise were recorded.

Abandoned Explosives.

Intending tenants of a vacant Belmont house found half-a-dozen gelignite plugs alongside electric detonators in a kitchen cabinet drawer a few feet from a stove. Unfortunately police efforts to apprehend the culprit were unavailing.

Two instances of apparently forgotten explosives secreted in cars under sale or repair were reported and dealt with.

Conferences and Meetings

Mr. Greaves' presence at four Standards Association of Australia meetings was chronicled under that heading. Whilst away, he conferred to advantage with Eastern States authorities on other departmental matters, particularly in relation to dangerous goods and flammable liquid controls.

The writer attended the eighth Australian and New Zealand Explosives Conference in Wellington and Auckland, commencing February 15th. A record number of agenda items came under discussion. Delegates were taken on visits to places of technical interest including a geothermal power station, a smallarms powder and filling plant and a modern firework factory, unique in that certain traditional manual operations had been replaced by mechanisation.

A two day meeting of the Australian Dangerous Goods Transport Sub-Committee at Melbourne was also attended, and followed by discussions on explosives transport with a delegate from the N.S.W. Railways.

Fireworks—Shopgoods Class.

Although the 1965 importations exceeded those of the previous year, very few accidents were reported. The usual inspections determined that quality accorded with requirements except for three Japanese fireworks which were borderline in chemical composition but banned essentially because of undue and erratic delay in firing after igniting the touchpaper. A revolving firework, rejected on its tendency to shed burning propellant charges, reappeared later in acceptably improved form.

Conditions relating to firework sales and the date of celebration remained unchanged.

Display Fireworks.

Popularity of displays increased without recorded mishap to operatives and spectators during the actual firing. Concern was felt, however, on the possibility of unexploded residues being picked up by children. The pyrotechnician must safeguard any surplus material and assume responsibility for undischarged oddments in the firing arena. But if, say, a rocket star-ejection charge failed during flight, a dangerous article would land, perhaps far from the launching point.

Complaints of excessive noise from displays, sometimes late at night, were recorded. Some alleviation might accrue from restricting the firing to early evening, as done in recently issued permits. To set upper limits of noise level appeared impracticable, for even if bursting and propellant charges were reduced, factors such as wind direction and proximity of reflective surfaces, including cloud, could produce unpredictably variable sound effects at given distances.

Amateur Rocketry.

A lad who had obviously studied the subject sought permission to construct and fire a rocket on his parents' property near the Perth Airport. Though not denied the right to experiment he was advised considerably to modify the composition and size originally intended—and the Civil Aviation Department had a good deal to say about missiles and low-flying aircraft.

Conclusion.

The characteristic individual and team work by the staff, coupled with the courtesy, co-operation and assistance extended by Government Departments, colleagues and contacts too numerous to mention, carried another year through to successful conclusion.

F. F. ALLSOP,
Chief Inspector of Explosives.

DIVISION IX

Report of Superintendent, Mine Workers' Relief Act, 1965 and Chairman, Miners' Phthisis Board

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 1965.

General

The State Public Health Department, under arrangements made with this Department, continued the periodical examination of mine workers, the work being carried out through the year at the State X-ray Laboratory, Kalgoorlie, and a mobile X-ray unit visited the Coolgardie, Yilgarn, Dundas, Phillips River, North Coolgardie, East Murchison, Murchison, Yalgoo, Pilbara and West Pilbara Goldfields and the South West Mineral Field. In addition mine workers on Koolan and Cockatoo Islands were examined using company equipment.

Mine Workers' Relief Act

Total Examinations

The examinations under the Mine Workers' Relief Act during the year totalled 4,314 as compared with 4,155 for the previous year, an increase of 159. The results of examinations are as follows:—

Normal	3,770
Silicosis early previously normal	53
Silicosis early previously silicosis early	459
Silicosis advanced previously normal	Nil
Silicosis advanced previously silicosis early	6
Silicosis advanced previously silicosis advanced	Nil
Silico-tuberculosis previously normal	Nil
Silico-tuberculosis previously silicosis early	1
Silico tuberculosis previously silicosis advanced	Nil
Tuberculosis previously normal	5
Asbestosis early previously normal	2
Asbestosis early previously asbestosis early	8
Silico-asbestosis early previously normal	3
Silico-asbestosis early previously asbestosis early	7
Total	4,314

These 1965 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 the examination figures, I desire to make the following comments:—

Normal, etc.—These numbered 3,770 or 87.39% of the men examined and include men having first class lives or suffering from fibrosis only. The figures for the previous year being 3,484 or 83.85%.

Early Silicosis.—These numbered 512 of which 53 were new cases and 459 had been previously reported, the figures for 1964 being 64 and 561, respectively. Early silicotics represent 11.87% of the men examined, the percentage for the previous year being 15.04%.

Advanced Silicosis.—There were six cases reported all of which advanced from early silicosis during the year. Advanced silicotics represent 0.14% of the men examined, the percentage for the previous year being 0.24%.

Silicosis Plus Tuberculosis.—One case was reported which was the same number as in 1964.

Tuberculosis Only.—Five cases were reported compared with two in 1964.

Asbestosis.—Twenty cases of early asbestosis were reported. Five were new cases and 15 had previously been reported. Cases of asbestosis represented 0.46% of the total examinations while in 1964 the percentage was 0.80%.

Mines Regulation Act.

Total Examinations.

Examinations under the Mines Regulation Act totalled 2,376. These were in addition to the 4,314 under the Mine Workers' Relief Act. There was an increase of 597 examinations under this Act in 1965 as compared with those in 1964. Of the total of 2,376 men examined, 2,101 were new applicants and 275 were re-examinees.

Analyses of Examinations.

Particulars of examinations are as follows:—

New Applicants.

Normal	2,068
Silicosis early	4
Early silicosis with tuberculosis	1
Tuberculosis	3
Other conditions	25
Total:	2,101

Re-examinees.

Normal	267
Early silicosis	5
Tuberculosis	1
Other conditions	2
Total:	275

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 Mine Regulation Act:—

Initial Certificates (Form 2)	2,336
Temporary Rejection Certificates (Form 3)	9
Rejection Certificates (Form 4)	27
Re-admission Certificates (Form 5)	3
Special Certificates (Form 9)	1
No certificate issued	—
Total:	2,376

Miner's Phthisis Act.

The amount of compensation paid during the year was £7,837 15s. 9d. compared with £8,832 12s. 8d. for the previous year.

The number of beneficiaries under the Act as on the 31st December, 1965, was 59, being 4 ex-miners and 55 widows.

Administrative.

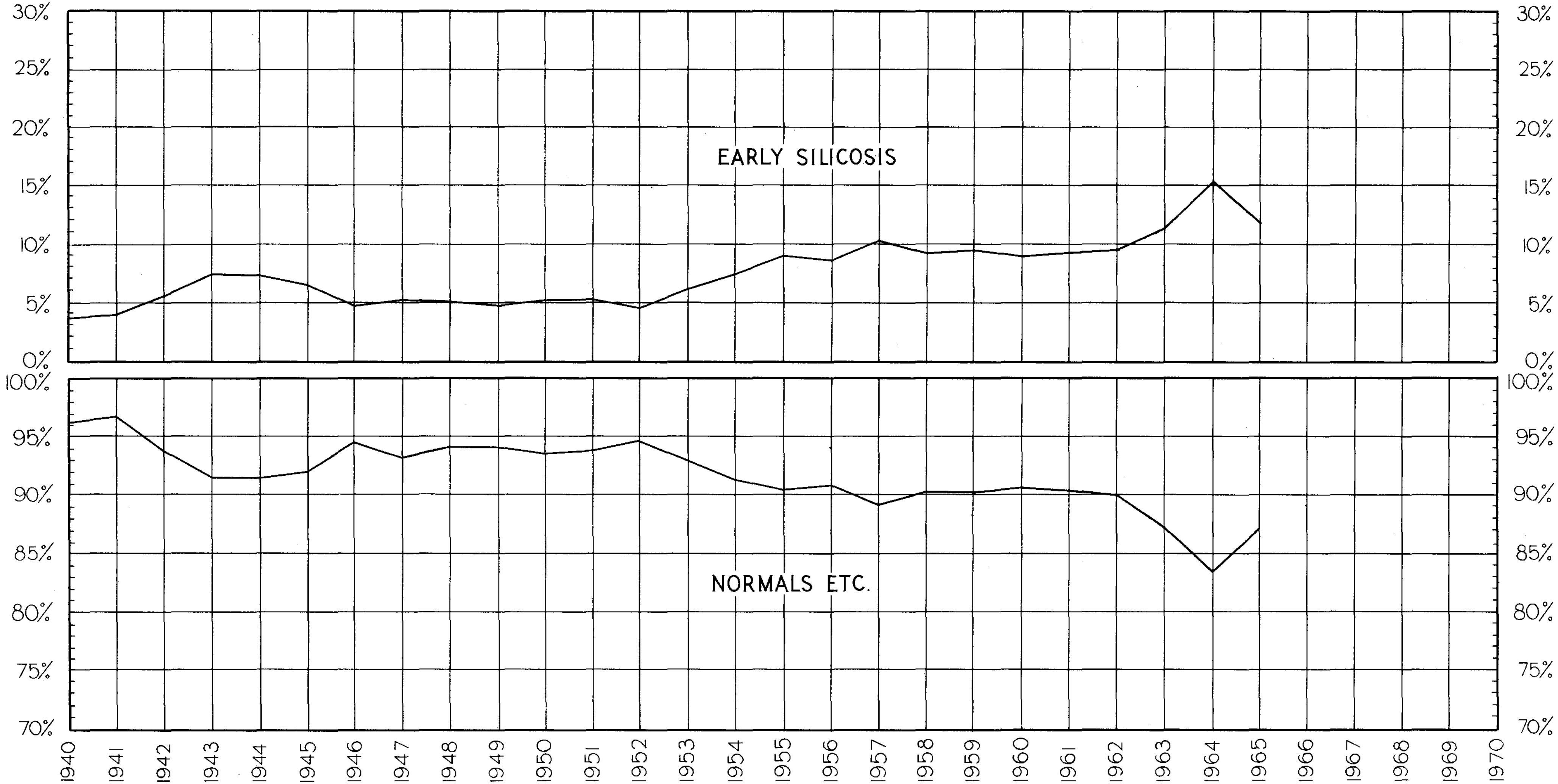
During the year both Mr. Ince and Mr. Jennings retired from the Board of the Mine Workers' Relief Fund after many years of very valuable service, and they were replaced by Mr. J. Bowman and Mr. G. F. Deas.

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 № 2

Showing Percentages of Silicosis Advanced, Silicosis plus Tuberculosis and Tuberculosis only, from 1940 onwards

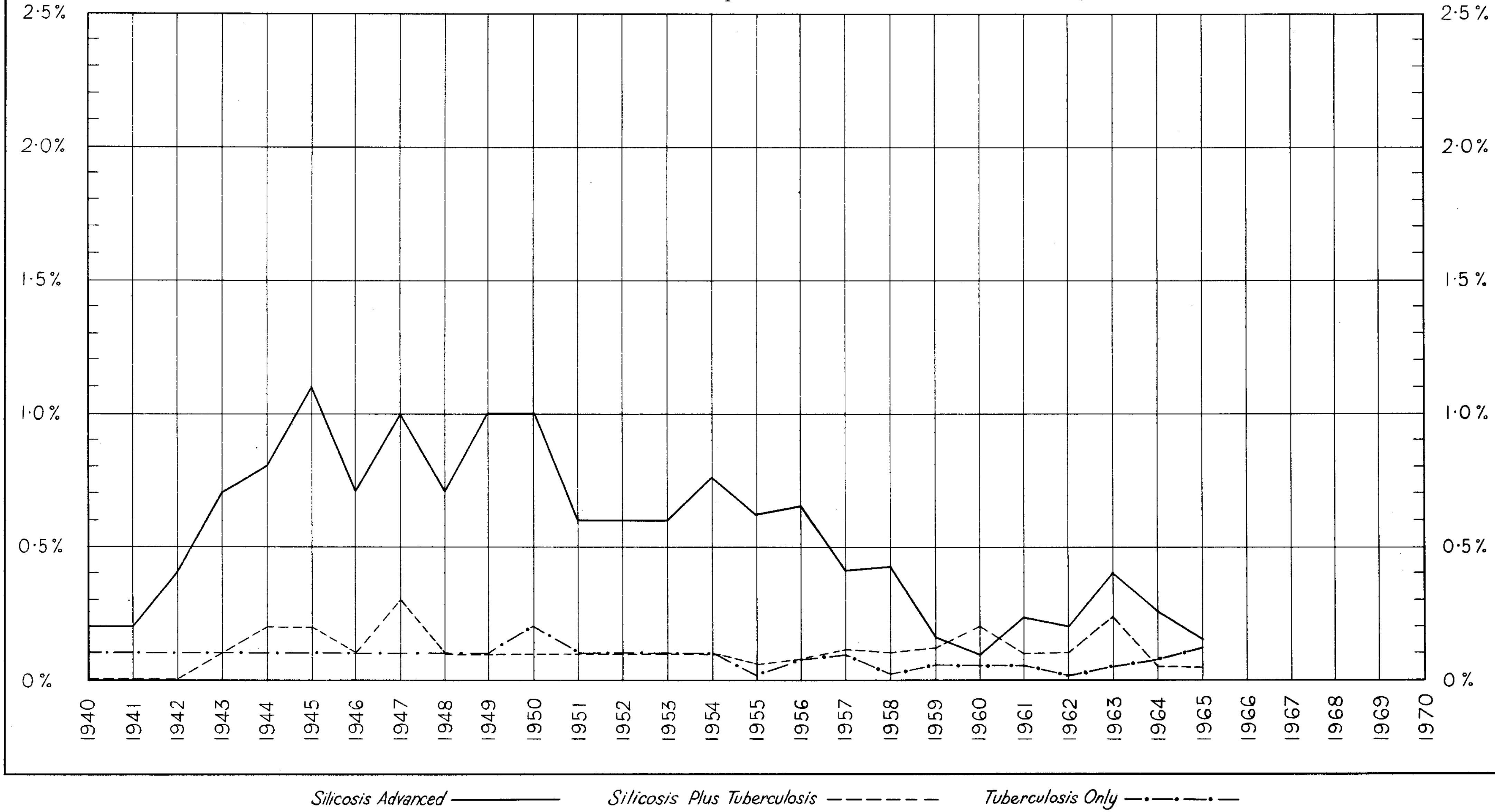


TABLE SHOWING RESULTS OF PERIODICAL EXAMINATION OF MINE WORKERS FROM INCEPTION OF EXAMINATIONS (1925).

	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	261	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
1965	3,770	87·39	53	459	512	11·87	....	6	....	6	·14	....	1	....	1	.02	5	.12	5	15	....	....	....	....	....	20	.46	4,314

DIVISION X

Report of the Chief Draftsman for the Year 1965

Under Secretary for Mines:

For the information of the Hon. Minister for Mines I herewith submit my report on the operation of the Survey and Mapping Branch for the year ended 31st. December, 1965.

Staff

Membership of the staff now totals 43 officers comprising 4 females and 39 males.

There were 5 resignations, to mining companies, during the year, but replacements were duly appointed.

Cadet Cartographers J. Regan, M. Jones, T. Moran and P. Jones became eligible for permanent appointment, whilst the remaining 8 cadets qualified well in their respective examinations.

Mr. E. Beasley, who was appointed last year under the "Trainee Drafting Assistant Scheme" was awarded a part time scholarship by the Technical Education Division entitling him to two years tuition with a grant of $100 per annum, for having gained high marks in his Diploma of Cartography course.

Demand for maps and plans by domestic and overseas mining interests continued to increase.

Cadastral survey requirements of mining tenements throughout the State have also correspondingly increased.

With the acquisition of new equipment and supplies of the latest plastic drawing and photographic media to hand, morale is extremely good within the Branch with all personnel taking keen interest in their part in the exploration of our mineral resources.

Reports in summarised form, of the sections of the Branch are as follows:—

A. A. HALL,
Chief Draftsman.

Surveys:

Contract surveys in accordance with Mines Department regulations to the value of £11,416 were carried out during the year, at the following centres:—

South West Mineral Field:
- Koolanooka
- Lake Grace
- Wanneroo
- Capel
- Yanchep
- Serpentine
- Marchagee
- Yelbini

Yilgarn Goldfield:
- Southern Cross
- Bullfinch
- Marvel Loch
- Mt. Palmer
- Blackbornes
- Manxman
- Mt. Caudan

Phillips River:
- Ravensthorpe
- Kundip

Ashburton Goldfield:
- Uaroo
- Range Station
- Wyloo
- Mt. Florry
- Monte Carlo
- Wandagee
- Yarraloola
- Red Hill

Gascoyne Goldfield:
- Mangaroon
- Mooloo Downs
- Nanga

Pilbara Goldfield:
- Moolyella
- Spear Hill
- Hartigan
- Coomba Creek
- Hillside
- Shaw River
- Old Shaw

West Pilbara Goldfield:
- Whim Creek
- Mons Cupri

Northampton Mineral Field:
- Galena
- Northampton

Coolgardie Goldfield:
- Ryans Find
- Little Nipper

Greenbushes Mineral Field:
- Greenbushes

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:—

H50-12-469—
- Bungalbin 80

H50-12-489—
- Lake Seabrook 80

F49-13-99
- Farquhar 80

F49-13-89—
- Warrora 80

F50-4-69—
- Mulyie 80

F50-4-68—
- Strelley 80

F50-7-22—
- Pilbara 80
- Pilbara 20-3

F50-3-4—
- Balla Balla 80

F50-7-15—
- Croydon 80

F50-7-16—
- Satirest 80
- Satirest 20-10
- Satirest 20-15

Mapping.

1. Three hundred and fifteen technical plans were prepared and drawn for Geological Surveys together with 7,615 prints from various originals.

1 : 250,000 Mapping.

Drafting was completed on Roebourne, Roy Hill, Widgiemooltha, Port Hedland, and Newman Geological Sheets which were forwarded for publication.

1 : 50,000.

Mt. King, Mooratherra, and Mt. Frederick sheets were published during the year.

1 : 2,500,000.—State Geological Map.

A new State Geological Map prapared on the existing base and involving 20 colours was produced as a provisional edition.

The map will be entirely reprinted later on a new base now under compilation on Albers projection.

Miscellaneous reproductions for Chemical Laboratories, Explosive and Inspection of Machinery Branches were carried out.

Certificates and time tables were prepared for School of Mines.

Dyeline prints and duplicates of all types produced during the year amounted to 19,721.

An Omnigraph "Fotokopist" machine was installed during the year. This machine possessing an enlargement reduction factor of 1 : 10 has proved of inestimable value and with the proposed additional photographic attachments will further increase its value as a drafting aid.

Conversion of printed maps and diagrams to film positive by use of the dyeline machine and an electric developer redesigned by this branch has greatly increased output and eliminated much time-consuming hand copying.

Public Plan Section:

During the year the following applications were received and chartered on public plans.

Mining tenements (Prospecting Areas, Claims, Leases etc.)	1,467
Temporary Reserves	467
Licenses to Prospect (Oil)	30
Permits to Explore (Oil)	2

A total of 1,287 plans were produced for sale purposes during the year, in addition to numerous special purpose plans.

Three hundred and eighty five searches to determine land tenure and mineral ownership have been carried out, an increase of 50 per cent. on the previous year, and rapidly expanding to accommodate increasing public demand.

The following provisional 1 : 50,000 Series plans have been compiled and put into the public plan system.

Kimberley Goldfield—

R712 Sheet—

4462—II McIntosh.

4461—I Sophie Downs.

4461—IV Halls Creek.

4361—II Mt. Angelo.

The following is nearing completion and should be in use early in 1966.

R712 Sheet 4461—II Palm Springs.

MINING STATISTICS
to 31st December, 1965

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Table of Contents

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TABLE 1

PRODUCTION OF GOLD AND SILVER FROM ALL SOURCES, SHOWING IN FINE OUNCES THE OUTPUT AS REPORTED TO THE MINES DEPARTMENT DURING 1965, 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.)

Kimberley Goldfield.

Mining Centre	Number of Lease	Registered Name of Company or Lease	Total for 1965: Alluvial	Total for 1965: Dollied and Specimens	Total for 1965: Ore treated	Total for 1965: Gold therefrom	Total for 1965: 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.
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	....	Voided leases	....	....	....	....	....	....	16.05	16,031.45	11,366.29	2.14
		Sundry claims	....		....	....	....	12.71	....	281.25	183.30	....
From Goldfield generally :—												
Sundry claims			....	....	....	....	....	....	....	....	....	†20.98
Reported by Banks and Gold Dealers			....	11.11	....	....	....	8,920.90	1,986.66	.75	8.15	....
Total			....	**11.11**	....	....	....	**9,097.68**	**3,027.46**	**22,931.90**	**17,281.87**	**128.76**

West Kimberley Goldfield.

Mining Centre	Number of Lease	Registered Name of Company or Lease	Total for 1965: Alluvial	Total for 1965: Dollied and Specimens	Total for 1965: Ore treated	Total for 1965: Gold therefrom	Total for 1965: Silver	Total Production: Alluvial	Total Production: Dollied and Specimens	Total Production: Ore treated	Total Production: Gold therefrom	Total Production: Silver
Napier Range	M.C. 29	Devonian Silver Lead Mine	....	....	....	....	†7,965.82	....	....	....	....	†33,197.57
From Goldfield generally :—												
Sundry claims			....	....	....	....	....	....	13.76	1.00	2.49	....
Reported by Banks and Gold Dealers			....	....	....	....	....	1.30	10.92	....	....	....
Total			....	....	....	....	**†7,965.82**	**1.30**	**24.68**	**1.00**	**2.49**	**33,197.57**

(15)—25843

Pilbara Goldfield.

MARBLE BAR DISTRICT.

Bamboo Creek	G.M.L. 1120	Bamboo Queen	....	....	....	....	....	....	....	88.50	30.99	.34
	1118	Kitchener	....	....	28.00	196.75	....	....	....	319.00	504.72	3.53
	1203	Mt. Prophecy	....	....	228.75	90.78	3.74	....	....	767.75	326.83	27.00
	1095 (1096) (1097)	Mt. Prophecy leases	....	....	....	....	....	....	24.50	3,053.00	1,096.72	49.63
	1072	Princess May	....	....	....	....	....	....	....	92.50	24.27	....
	924	True Blue	....	....	....	....	....	.62	....	4,671.25	114.64	.22
		Voided leases	....	....	....	....	....	13.54	572.09	59,841.35	62,579.94	304.99
		Sundry claims	....	....	....	....	....	8.97	307.83	5,208.85	3,034.45	7.21
Boodalyerie	....	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	....	....	13.50	32.23	....	....	....	8,139.25	7,891.02	....
Marble Bar	G.M.L. 930 (956)	Alexander Leases	....	....	....	....	....	....	....	354.50	120.94	.81
	930	Alexander	....	....	....	....	....	....	....	640.00	114.59	....
	1094	Blue Bar	....	....	....	....	....	....	....	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	....
	1209	Ironclad	....	....	156.00	12.70	.20	....	....	156.00	12.70	.20
	1121	Little Portree	....	....	....	....	....	....	....	103.00	66.88	6.93
	1214	Stray Shot	....	....	130.50	5.40	....	....	....	130.50	5.40	....
		Voided leases	....	....	....	....	....	45.98	199.09	165,602.49	150,726.16	595.61
		Sundry claims	....	....	....	....	....	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	....	....	....	....	....	128.39	579.91	179.75	121.72	.05
Pilgangoora	1208	Birthday Gift	....	....	66.25	61.65	....	....	....	103.25	115.00	....
		Voided leases	....	....	....	....	....	16.65	....	2,279.00	407.57	....
		Sundry claims	....	....	....	....	....	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 1965: Alluvial	Total for 1965: Dollied and Specimens	Total for 1965: Ore treated	Total for 1965: Gold therefrom	Total for 1965: 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.
		PILBARA GOLDFIELD—continued. MARBLE BAR DISTRICT—*continued.*										
Warrawoona	1193	Trump	....	....	60.00	2.29	....	....	....	349.50	27.33	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	64.47	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	....	....	....	....	....	....	....	40.00	*12,156.01	371.34
		State Battery, Marble Bar	....	....	....	*80.63	6.01	....	....	12.00	*12,951.04	151.75
		A. Crowe & J. Olive (L.T.T. 1602H)	....	....	169.00	*9.71	.19	....	....	169.00	*9.71	.19
		Various Works	....	....	....	....	....	....	....	380.95	*1,924.48	5.96
Reported by Banks and Gold Dealers			5.60	....	....	....	....	14,628.26	457.21	....	15.41	2,224.95
		Total	**5.60**	....	**852.00**	**492.14**	**10.14**	**15,510.47**	**4,569.14**	**343,705.02**	**331,765.57**	**34,002.76**
		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	....	....	20.00	2.09	...	....	...	125.00	8.61	....
	231L etc.	North West Mining N.L.	....	....	....	....	...	....	...	9,782.07	6,174.22	....
		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	...	....	....	...	.	....	18.69	6,792.60	2,645.65	2.38

Mosquito Creek	331L	Ord 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	....	....	....	....	....	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	....	....	26.00	2.82	....	321.36	689.71	6,689.45	10,577.95	18.62
Spinaway Well .... Twenty Mile Sandy	314L	Copper Hills Copper Mine	....	....	....	....	....	....	....	....	‡15.44	‡483.78
		Voided leases	....	....	....	....	....	....	16.97	7,243.70	9,008.65	371.70
		Sundry claims	....	....	22.00	2.82	....	33.10	30.50	7,815.85	6,286.11	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	2.58	....	....	....	....	10,125.28	147.52	....	48.03	6.12
		Total	**2.58**	....	**68.00**	**7.73**	....	**10,509.53**	**2,909.69**	**150,042.42**	**135,457.21**	**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	G.M.L 177	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*—continued.

Mining Centre	Number of Lease	Registered Name of Company or Lease	Total for 1965: Alluvial	Total for 1965: Dollied and Specimens	Total for 1965: Ore treated	Total for 1965: Gold therefrom	Total for 1965: 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.
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.

Mining Centre	Number of Lease	Registered Name of Company or Lease	Total for 1965: Alluvial	Total for 1965: Dollied and Specimens	Total for 1965: Ore treated	Total for 1965: Gold therefrom	Total for 1965: Silver	Total Production: Alluvial	Total Production: Dollied and Specimens	Total Production: Ore treated	Total Production: Gold therefrom	Total Production: Silver
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 (Lead Ores)		....	....	....	....	....	....	....	....	....	†33,787.67
	Reported by Banks and Gold Dealers		....	....	....	....	....	8,891.48	123.17	....	7.12	....
		Total	....	....	....	....	....	**9,268.52**	**482.46**	**6,807.10**	**2,913.43**	**41,971.38**

Gascoyne Goldfield.

Mining Centre	Number of Lease	Registered Name of Company or Lease	Total for 1965: Alluvial	Total for 1965: Dollied and Specimens	Total for 1965: Ore treated	Total for 1965: Gold therefrom	Total for 1965: Silver	Total Production: Alluvial	Total Production: Dollied and Specimens	Total Production: Ore treated	Total Production: Gold therefrom	Total Production: Silver
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	....	....	98.00	260.11	11.34	....	3.50	558.75	1,287.30	44.01
		Sundry claims	....	....	....	....	....	....	49.09	97.00	376.12	26.92
	From Goldfield generally :—											
	Reported by Banks and Gold Dealers		....	....	....	....	....	609.52	28.97	....	2.56	....
		Total	....	....	**98.00**	**260.11**	**11.34**	**698.49**	**121.33**	**1,042.75**	**2,183.27**	**70.93**

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	Horseshoe Lights	....	....	....	....	....	....	....	9,549.00	1,255.34	.34
	568P	Prior to transfer to present holders	....	....	....	....	....	....	....	139,786.00	23,765.24	1,407.05
		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	....	52.57	....	....	1.92	61.51	377.54	35,365.35	9,030.99	5.35
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 :											
		D. Collis (L.T.T. 1569H)	....	....	1,304.00	*48.35	1.48	....	....	1,304.00	*48.35	1.48
		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	....	**52.57**	**1,304.00**	**48.35**	**3.40**	**3,387.79**	**5,371.79**	**783,070.73**	**322,738.34**	**3,793.90**

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.S 1363 1364, (1366)	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	....	....	98.50	21.75	1.33	401.71	451.61	17,805.98	9,801.02	275.42

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 1965					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 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	....	....	652.00	746.80	24.68	....	....	737.00	893.17	30.93
	1382, 1383	Rowley's Find Leases	....	....	526.00	195.63	2.27	....	....	773.00	314.44	6.21
	(1367)	Tahmoo	....	....	603.00	200.18	....	....	....	1,634.00	599.50	.50
	1386	Wedge Extended	....	....	22.00	23.82	....	....	....	58.00	31.81	.43
		Voided leases	....	....	....	....	....	....	....	63.50	7.67	.50
		Sundry claims	....	....	125.00	50.34	2.40	143.23	....	997.75	582.34	29.71
	From District Generally :—											
	Sundry Parcels treated at :											
	Various Works		....	....	....	....	....	2.12	2.35	1,774.03	*39,822.19	984.03
	Reported by Banks and Gold Dealers		.13	....	....	....	....	6,458.93	101.91	.05	10.00	....
		Total	**.13**	....	**2,026.50**	**1,238.52**	**30.68**	**7,103.51**	**2,343.19**	**2,017,119.67**	**825,469.51**	**27,261.15**
		WILUNA DISTRICT.										
Coles	....	Voided leases	....	....	....	....	....	....	....	2,765.50	1,240.40	....
		Sundry claims	....	....	....	....	....	....	21.03	3,909.50	1,531.71	1.40
Corboys 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. Eurika	....	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	....	....	....	....	....	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)	....	....	....	*4.78	1.58	....	....	....	*103.49	20.30
		Various Works	....	....	....	....	....	....	....	776.00	*29,001.12	232.42
		Reported by Banks and Gold Dealers :	....	....	....	....	....	63.66	56.58	....	158.54	12.02
		Total	....	....	....	**4.78**	**1.58**	**236.48**	**1,254.11**	**8,873,649.69**	**1,872,319.97**	**10,322.32**

BLACK RANGE DISTRICT.

Barrambie	G.M.L. 1117B	Scheelite Leases	....	....	....	....	....	....	....	1,031.50	658.95	11.02
		Voided leases	....	....	....	....	....	....	22.49	18,558.42	17,584.28	125.80
		Sundry claims	....	....	....	....	....	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	....	....	....	....	....	....	120.68	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	....
Errolls	....	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	....	....	....	....	....	50.27	1,458.98	7,697.40	2,966.37	....
Sandstone	G.M.L. 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	....	....	....	....	....	44.95	1,421.07	16,007.95	6,931.08	....
Youanmi	....	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 :—										
		State Battery, Sandstone	....	....	....	....	....	....	....	290.50	*23,575.34	61.02
		Various Works	....	....	....	....	....	....	....	144.50	*17,000.81	....
		Reported by Banks and Gold Dealers	....	....	....	....	....	1,495.40	54.36	....	20.38	.15
		Total	....	....	....	....	....	**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 1965					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.
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	....	....	....	....	....	252.92	894.70	47,462.99	20,562.99	5.13
Eelya	G.M.L. 2286	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	2289	New Rand	....	....	528.50	121.91	7.76	....	....	1,346.75	303.41	16.75
	2287	Rand No. 3	....	....	....	....	....	....	....	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	....	....	....	....	....	....	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
Tuckenarra	....	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	.13
Wild 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 :											
	State Battery, Cue	....	....	....	....	....	....	....	....	76.25	*26,818.66	127.53
	M. Hronsky (L.T.T. 1467H)	....	....	....	....	*40.91	66·47	....	....	....	*269.02	627.61
	Various Works	....	....	....	....	....	....	....	....	8,615.52	*36,008.51	1,232.12
	Reported by Banks and Gold Dealers	....	....	....	....	....	....	3,443.93	109.87	....	22.62	.65
		Total	....	....	528.50	162.82	74.23	5,124.31	9,104.99	6,815,391.31	1,402,653.25	274,758.89

MEEKATHARRA DISTRICT.

Abbotts	....	Voided leases	....	....	....	....	....	....	26.45	36,841.35	38,775.28	....
		Sundry claims	....	....	....	....	....	....	5.29	3,951.57	2,357.54	....
Burmakura	....	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	....	....	91.00	14.14	1.22	....	42.19	1,160.05	790.83	1.22
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	....	....	2,401.50	124.34	5.17	....	....	4,254.50	225.31	8.99
	1559N	Ingliston	....	....	....	....	....	....	498.32	3,223.85	1,895.45	.32
	1529N	Prohibition	....	....	106.00	9.94	.13	....	....	10,193.75	2,481.25	11.52
	1529N, etc.	Prior to transfer to present holders	....	....	....	....	....	....	....	54,266.25	9,949.61	11.83
		Voided leases	....	....	....	....	....	181.39	1,708.02	1,717,864.82	929,364.72	2,475.39
		Sundry claims	....	126.68	....	....	4.94	279.84	1,136.42	32 074.45	11,660.80	9.68
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	....
Nanadie Well	G.M.L. 2003N....	Poplar	....	....	94.75	152.86	8.45	....	....	143.00	281.84	15.85
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	....
Ruby Well	....	Voided leases	....	....	....	....	....	....	43.46	7,461.00	4,046.70	....
		Sundry claims	....	....	....	....	....	1,015.87	409.39	520.25	629.60	....

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 1965: Alluvial	Total for 1965: Dollied and Specimens	Total for 1965: Ore treated	Total for 1965: Gold therefrom	Total for 1965: 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.*										
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	....	....	60.00	9.51	.47	....	....	10,579.50	3,051.28	3.04
		Voided leases	....	....	....	....	....	19.03	1,972.23	28,175.54	14,609.36	8.68
		Sundry claims	....	....	55.00	1.99	.09	61.89	647.51	11,743.67	5,119.66	1.02
		From District generally :—										
		Sundry Parcels treated at :										
		State Battery, Meekatharra	....	....	....	*323.92	....	....	....	193.00	*28,898.21	25.13
		F. M. Scott (L.T.T. 1506H)	....	....	....	*41.45	4.28	....	....	49.00	*298.65	38.87
		Various Works	....	....	....	....	....	....	....	3,947.30	*13,962.97	391.20
		Reported by Banks and Gold Dealers	50.76	112.43	....	....	8.32	12,310.55	297.96	451.50	97.71	10.55
		Total	**50.76**	**239.11**	**2,808.25**	**678.15**	**33.07**	**14,700.99**	**18,499.14**	**2,317,370.06**	**1,310,467.93**	**5,267.35**
		DAY DAWN DISTRICT.										
Day Dawn	G.M.L. 573D etc.	Mountain View Gold N.L.	....	....	40.50	9.75	1.12	....	....	13,832.85	17,445.73	223.74
		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	36.11	....	17.75	12.07	4.08	104.98	965.49	3,680.94	1,373.06	9.75
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	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	....	....	....	....	....	2,223.92	37.47	....	12.57	.01
		Total	36.11	....	58.25	21.82	5.20	3,291.17	11,341.80	2,037,595.63	1,375,641.81	169,447.42

MOUNT MAGNET DISTRICT.

Jumbulyn....	G.M.L. 1410M	Gold Bug	....	....	....	....	....	....	2.20	927.35	277.15	....
		Voided leases	....	....	....	....	....	....	13.37	724.10	378.24	1.17
		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
		Voided leases	....	....	....	....	....	....	3,226.91	151,752.55	128,851.38	467.92
		Sundry claims	....	....	....	....	....	26.00	108.82	15,435.52	6,003.48	9.23
Mt. Magnet	1527M	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	....	....	....	....	....	1.82	....	18,042.75	12,901.93	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.	....	....	164,671.00	54,232.29	4,194.08	....	....	2,369,984.40	1,146,029.56	52,896.69
		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
	G.M.L. 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	....	....	160.50	55.28	3.58	157.95	2,626.24	61,550.67	30,149.38	23.93
Mt. Magnet, East	....	Voided leases	....	....	....	....	....	63.29	764.53	5,522.28	2,811.75	....
		Sundry claims	....	....	....	....	....	....	37·22	418·25	428·29	....
Moyagee	....	Voided leases	....	....	....	....	....	....	23.59	12,472.85	18,334.04	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	....
		From District Generally :—	....	....								
		Sundry Parcels treated at :										
		State Battery, Boogardie	....	....	....	....	....	....	....	348.26	*35,102.45	15.62
		Various Works	....	....	....	....	....	....	....	100.56	*19,309.19	36.75
		Reported by Banks and Gold Dealers	.83	....	....	....	....	2,318.70	114.69	8.00	113.15	.26
		Total	.83	....	164,831.50	54,287.57	4,197.66	2,636.13	20,467.75	3,531,072.62	1,767,296.53	59,703.07

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 1965					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.
Yalgoo Goldfield.												
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	....
Messengers 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	1,152.60	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 claims	....	....	....	....	....	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	....	....	.81	....	....	....	965.19	59.13	....	48.90	.89
		Total	....	**.81**	....	....	....	**1,808.77**	**2,018.88**	**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
Linden	....	Voided leases	....	....	....	....	....	7.53	566.97	72,919.81	66,208.35	.68
		Sundry claims	....	....	43.00	20.73	.60	132.11	244.96	19,710.35	13,886.99	2.29
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	....	....	....	....	....	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	....	....	36.00	16.49	....	....	113.84	1,219.57	658.94	....

Table I.—*Production of Gold and Silver from all sources, etc.*—continued.

MOUNT MARGARET GOLDFIELD—continued.
MOUNT MORGANS DISTRICT.

Mining Centre	Number of Lease	Registered Name of Company or Lease	Total for 1965 Alluvial	Total for 1965 Dollied and Specimens	Total for 1965 Ore treated	Total for 1965 Gold therefrom	Total for 1965 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.
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		3.64	....	....	....	....	3,161.36	141.84	10.30	95.75	.68
		Total	**3.64**	....	**79.00**	**37.22**	**.60**	**3,574.87**	**9,401.98**	**1,217,999.31**	**717,985.31**	**5,831.33**

MOUNT MALCOLM DISTRICT.

Mining Centre	Number of Lease	Registered Name of Company or Lease	Total for 1965 Alluvial	Total for 1965 Dollied and Specimens	Total for 1965 Ore treated	Total for 1965 Gold therefrom	Total for 1965 Silver	Total Production Alluvial	Total Production Dollied and Specimens	Total Production Ore treated	Total Production Gold therefrom	Total Production Silver
Cardinia	....	Voided leases	....	....	....	....	....	13.87	1,598.15	5,531.74	4,238.57	....
		Sundry claims	....	....	19.00	44.21	1.00	4.25	121.91	2,007.25	714.85	6.60
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	....
Dodgers 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	....	....	695.00	58.84	.84	....	....	9,005.25	696.03	9.46
	1851C	Monte Carlo	....	....	117.00	12.34	....	....	....	117.00	12.34	....
		Voided leases	....	....	....	....	....	....	4,482.18	74,717.46	52,293.77	7.56
		Sundry claims	....	....	105.50	62.77	4.31	129.92	906.52	12,274.12	6,776.73	45.18
Leonora	G.M.L.'s 1763C,	Sons of Gwalia Ltd.	....	....	....	....	....	....	....	7,030,740.53	2,580,851.91	188,804.14
	etc.	Prior to transfer to present holders	....	....	....	....	....	....	....	109,081.00	55,989.21	8.66
		Voided leases	....	....	....	....	....	....	2,452.07	179,084.50	93,505.01	110.02
		Sundry claims	....	....	178.00	20.21	1.40	37.73	377.26	22,337.45	12,737.05	26.77
Malcolm	....	Voided leases	....	....	....	....	....	11.65	47.07	62,656.53	47,563.43	....
		Sundry claims	....	....	....	....	....	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	....	....	125.00	22.86	.55	5.42	85.74	3,391.41	2,321.64	.87
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	....	....	12.00	2.80	.16	4.68	54.46	1,712.16	1,436.00	1.12
	From District generally :—											
	Sundry Parcels treated at :											
	State Battery, Darlot		....	....	....	....	....	....	....	18.00	*2,514.77	4.98
	Various Works		....	....	....	....	....	....	....	809.50	*25,301.30	158.35
	Reported by Banks and Gold Dealers		....	....	....	....	....	3,653.16	252.83	46.50	57.80	.67
		Total	....	....	**1,134.50**	**211.69**	**8.26**	**4,066.98**	**16,668.99**	**7,752,932.47**	**3,069,645.37**	**190,781.96**

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	....
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		3.99	....	....	....	....	2,584.74	108.08	....	29.18	....
		Total	**3.99**	....	....	....	....	**4,147.53**	**9,354.35**	**2,528,173.24**	**1,174,043.56**	**66,190.70**

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 1965					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.												
MENZIES DISTRICT.												
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	Gull's Blow	1.90	2.50	....	....	....	1.90	167.25	374.75	265.78	....
		Voided leases	....	....	....	....	....	.94	1,385.26	29,897.79	18,124.83	....
		Sundry claims	....	....	28.00	3.71	....	46.46	2,144.42	2,980.60	3,402.32	....
Menzies	5793Z	Black Swan	....	....	624.75	44.72	....	....	....	1,421.25	103.92	....
	5794Z	Callie	....	....	96.50	24.77	....	....	....	315.50	85.32	....
	(5511Z)	First Hit	....	....	22.50	7.78	....	....	....	7,216.25	7,793.05	24.00
	(5511Z)	(First Hit Gold Mines (1934) Ltd.)	....	....	....	....	....	....	....	68,473.70	49,060.96	6,676.23
	(5788Z)	Flying Fish	....	....	88.75	4.57	....	....	11.06	532.25	59.83	.85
	5542Z	Good Block Lease	....	....	462.25	29.83	....	....	7.32	4,338.30	3,126.24	....
	5780Z	Good Enough	....	....	....	....	....	....	....	3,864.70	1,041.58	1.54
	5520Z	Mignonette	....	....	....	....	....	....	....	808.50	404.43	....
		Voided leases	....	....	....	....	....	45.42	1,260.24	939,592.13	729,030.89	13,595.47
		Sundry claims	....	....	1,467.80	96.97	.66	56.87	624.33	42,108.39	26,458.59	813.76
Mt. Ida	5701Z etc.	Moonlight Wiluna Gold Mines Ltd.	....	....	25,338.00	12,986.57	2,053.96	....	40.77	424,162.86	219,700.86	5,666.35
		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	....	....	....	....	*6.86	....	....	....	20.00	*3,810.10	1,032.66
	Various Works	....	....	....	....	....	....	....	....	3,216.05	*58,804.12	3,062.11
	Reported by Banks and Gold Dealers	....	.97	....	....	....	....	1,496.96	403.22	100.00	48.49	....
		Total	**2.87**	**2.50**	**28,128.55**	**13,205.78**	**2,054.62**	**1,696.69**	**7,032.09**	**1,918,675.13**	**1,421,007.60**	**37,228.46**
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	

(16)—25843

Morleys	G.M.L. 1094U	First Hit	....	....	28.50	54.66	.49	....	82.48	5,377.50	7,313.48	11.89
	1168U	Hazel Dawn	....	....	....	....	....	....	....	51.25	104.97	....
	1081U	Mabel Gertrude	....	....	....	....	....	....	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	....	....	62.50	26.11	....	....	....	123.00	106.60	....
	1173U	Riverina	....	....	423.00	64.25	....	....	....	590.50	104.42	....
		Voided leases	....	....	....	....	....	....	274.09	136,088.82	117,634.66	530.82
		Sundry claims	....	....	21.00	5.81	.04	10.82	296.42	11,226.64	9,915.41	1.14
Mulwarrie	1153U	Four Mile	....	....	9.00	89.97	5.10	....	....	115.50	778.02	11.32
	1113U	Oakley	....	....	220.00	209.48	....	....	....	5,022.00	8,228.48	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	....
Warring	....	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	....	....	....	....	....	112.95	424.28	100.00	106.72	.01
		Total	....	....	**764.00**	**450.28**	**5.63**	**129.66**	**7,298.59**	**535,817.70**	**446,587.15**	**22,286.97**

NIAGARA DISTRICT.

Desdemona	....	Voided leases	....	....	....	....	....	....	7.12	9,809.00	7,555.81	12.04
		Sundry claims	....	....	....	....	....	....	10.35	2,225.45	892.48	....
Kookynie	G.M.L. (928G)	Altona	....	....	50.75	14.26	....	....	....	13,543.75	7,716.19	27.65
	911G	Cosmopolitan South	....	....	....	18.99	....	....	....	2,650.00	1,384.37	....
	940G	New Gladstone	....	....	5.50	3.63	....	....	....	386.75	72.66	.20
		Voided leases	....	....	....	....	....	3.35	347.30	745,952.71	394,988.56	5,376.87
		Sundry claims	....	....	51.00	12.34	....	60.92	106.60	9,513.80	6,973.25	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	....	....	51.25	15.42	....	32.60	283.40	8,092.58	4,128.44	....
From District generally :— Sundry Parcels treated at :												
		Various Works	....	....	....	....	....	....	....	1,220.50	*20,884.22	120.98
		Reported by Banks and Gold Dealers	....	....	....	....	....	1,593.51	823.66	....	63.53	....
		Total	....	....	**158.50**	**64.64**	....	**1,718.48**	**1,821.77**	**944,436.52**	**528,578.14**	**5,716.17**

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 1965					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.
		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	....	....	23.00	2.87	....	....	....	161.50	25.83	....
	1320R	Margaret	....	....	....	....	....	....	....	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
	1339R	Yilgangie	....	....	197.00	119.07	8.96	....	....	922.00	393.16	9.42
		Voided leases	....	....	....	....	....	6.30	87.08	45,573.75	21,404.41	2.00
		Sundry claims	....	....	76.00	17.44	....	.87	5.93	18,278.05	6,375.98	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	....	....	40.00	13.96	2.61	....	....	32,899.50	30,534.87	4,471.98
		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	.30	....	....	....	....	1,161.96	160.08	....	28.80	.09
		Total	**.30**	**....**	**336.00**	**153.34**	**11.57**	**1,312.27**	**3,817.12**	**296,815.78**	**178,348.78**	**5,344.76**

Broad Arrow Goldfield.

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
Bardoo	G.M.L. 2325W	Pride	....	....	99.25	98.05	....	....	....	136.50	333.21	....
		Voided leases	....	....	....	....	....	....	2,335.41	85,426.84	55,705.22	203.60
		Sundry claims	....	....	74.00	23.27	....	54.95	1,218.09	18,022.03	8,537.77	....
Black Flag	2229W....	Bellevue	....	....	....	....	....	....	212.68	4,136.48	3,256.47	9.92
	2320W....	Bellevue South	....	....	90.50	166.63	5.29	....	....	132.00	224.65	8.69
		Voided leases	....	....	....	....	....	27.81	405.90	48,428.54	28,212.48	2.04
		Sundry Claims	....	....	....	....	....	712·92	251·59	8,399·66	5,027·14	..

Broad Arrow	2317W	Twist	....	....	8.00	2.15	....	....	....	19.00	8.18	....
		Voided leases	....	....	....	....	....	70.32	10,453.81	155,909.94	120,089.44	20.23
		Sundry claims	....	8.32	748.75	50.23	.58	1,007.72	3,054.58	37,133.40	17,428.97	1.06
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	....	Voided leases	....	....	....	....	....	....	55.49	5,891.12	7,636.49	7.56
		Sundry claims	....	....	50.00	2.31	....	....	441.85	3,380.64	3,251.56	....
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	....	....	194.25	150.52	....	....	....	914.50	773.55	5.41
	2278W	Prince of Wales	....	....	203.50	388.20	9.40	....	....	1,211.00	1,998.25	56.51
	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	....	....	240.03	102.88	4.28	....	356.66	7,641.62	3,341.53	4.28
Ora Banda	G.M.L. S 2270W, 2290W	Gimlet South Leases	....	....	12,633.00	1,069.55	....	....	....	43,975.00	5,564.39	164.62
	2330W	Little Evelyn	....	....	10.75	16.89	....	....	....	10.75	16.89	....
	2300W	Sleeping Beauty	....	....	....	....	....	....	....	3,250.00	992.43	1.14
	2315W	Victorious	....	....	942.50	37.03	....	....	....	942.50	37.03	....
		Voided leases	....	....	....	....	....	....	846.13	423,666.52	151,214.10	1,685.77
		Sundry claims	....	....	124.00	29.34	....	....	467.18	16,204.80	4,961.18	....
Paddington	2298W	Rona Lucille	....	....	113.60	281.80	17.97	....	....	392.60	402.92	17.97
		Voided leases	....	....	....	....	....	5,566.30	463.31	196,486.56	86,485.99	32.15
		Sundry claims	....	....	63.25	11.91	....	1,714.16	291.43	17,644.93	9,341.65	....
Riche's Find	2306W	Cave Hill	....	....	8.75	3.93	....	....	238.15	75.85	154.93	....
		Voided leases	....	....	....	....	....	....	21.64	7,643.09	6,095.69	71.36
		Sundry claims	....	....	31.00	9.83	....	....	549.09	2,112.50	2,526.77	.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	1,400.01	.11
From Goldfield Generally :—												
Sundry Parcels treated at :												
		State Battery, Ora Banda	....	....	....	*599.88	....	....	....	128.05	*27,555.20	75.38
		Various Works	....	....	....	....	....	2,275.66	1.24	17,048.27	*53,850.36	3,105.75
		Reported by Banks and Gold Dealers	2.01	1.21	....	....	....	10,029.00	166.91	61.68	95.83	.15
		Total	2.01	9.53	15,635.13	3,044.40	37.52	21,992.52	28,005.48	1,403,014.79	749,926.00	5,649.06

Table I.—*Production of Gold and Silver from all sources, etc.*—continued

North-East Coolgardie Goldfield.

KANOWNA DISTRICT.

Mining Centre	Number of Lease	Registered Name of Company or Lease	Total for 1965 Alluvial	Total for 1965 Dollied and Specimens	Total for 1965 Ore treated	Total for 1965 Gold therefrom	Total for 1965 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.
Gindalbie	....	Voided leases	....	....	....	....	....	....	1,151.99	46,449.78	41,928.37	38.41
		Sundry claims	....	....	3.50	.63	....	....	716.52	5,860.77	3,310.03	.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	....	....	182.50	26.37	.16	24.70	269.72	1,675.00	1,052.74	.16
	1585X	New Kanowna	....	....	11.00	68.58	....	....	....	11.00	68.58	....
	1572X	Kanowna Red Hill	....	....	235.00	162.07	2.48	....	2.38	4,023.75	1,414.33	9.07
		Voided leases	....	....	....	....	....	24.94	4,516.76	685,625.60	380,504.87	2,482.24
		Sundry claims	....	....	25.00	4.47	....	125.32	2,169.07	28,505.07	12,181.01	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	4.43	....	....	....	....	106,037.88	40.42	.50	109.73	....
		Total	**4.43**	....	**457.00**	**262.12**	**2.64**	**106,543.26**	**13,526.67**	**1,010,319.56**	**627,680.19**	....

KURNALPI DISTRICT.

Mining Centre	Number of Lease	Registered Name of Company or Lease	Total for 1965 Alluvial	Total for 1965 Dollied and Specimens	Total for 1965 Ore treated	Total for 1965 Gold therefrom	Total for 1965 Silver	Total Production Alluvial	Total Production Dollied and Specimens	Total Production Ore treated	Total Production Gold therefrom	Total Production Silver
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.	....	....	186.75	65.19	....	....	....	232.75	80.84	....
		Prior to transfer to present holders	....	....	....	....	....	....	....	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	....	....	17.25	3.03	....	324.12	727.39	4,618.86	2,374.06	....
Mulgabbie....	457K	Mulgabbie Lucknow	....	....	....	....	....	....	....	70.00	6.72	....
		Voided leases	....	....	....	....	....	....	1,402.66	226.75	7,845.87	4.95
		Sundry claims	....	....	....	....	....	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	.63	....	....	....	....	12,108.34	70.70	....	2.35	1.49
		Total	**.63**	....	**204.00**	**68.22**	....	**12,837.27**	**8,298.91**	**14,383.07**	**19,125.12**	**12.71**

East Coolgardie Goldfield.

EAST COOLGARDIE DISTRICT.

Binduli	....	Voided Leases	....	....	....	....	....	....	....	1,904.60	495.36	....
		Sundry claims	....	....	99.25	14.53	.26	....	13.01	6,092.87	1,760.73	.34
Boorara	....	Voided leases	....	....	....	....	....	....	459.07	309,467.82	172,861.95	411.37
		Sundry claims	....	....	....	....	....	.49	145.56	4,272.09	1,592.56	.23
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	....
	5159E, etc.	Gold Mines of Kalgoorlie (Aust.) Ltd.	....	....	470,174.00	116,895.54	46,821.89	....	....	4,569,257.00	1,186,352.69	299,113.84
		Prior to transfer to present holders	....	....	....	....	....	....	849.95	15,916,923.07	6,416,710.17	819,123.37
	5695–5780E, 6254E	Great Boulder Proprietary Gold Mines Ltd.	....	....	387,894.00	92,346.50	60,385.97	....	1.53	15,840,049.97	6,843,931.45	1,750,901.03
	5478E, etc.	Lake View and Star Ltd.....	....	....	619,672.00	151,997.46	18,308.98	....	....	19,186,677.30	5,501,634.77	612,597.86
		Prior to transfer to present holders	....	....	....	....	....	....	8.49	15,792,500.38	9,149,223.80	1,348,055.82
	5413E, etc.	North Kalgoorlie (1912) Ltd.	....	....	364,561.00	76,042.74	37,539.21	....	127.55	7,576,251.24	1,980,896.11	528,209.41
	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	....	....	....	....	....	....	199.00	1,374.75	662.75	....
Hampton Plains	P.P.L. 277, Loc. 50	Joyce and Africh	....	....	907.75	182.99	1.47	....	....	11,864.75	1,004.89	1.48
	P.P.L. 476, Loc. 48	Ivy Rose	....	....	69.75	14.27	....	....	7.75	175.80	307.37	.72
	P.P.L. 448, Loc. 48	L. Lethlean	....	....	4.50	9.95	....	....	....	4.50	9.95	....
	P.P.L. 175A, Loc. 48	S. Shackleton	....	....	....	....	....	....	....	219.25	38.34	.27
	P.P.L. 280, Loc. 48	W. J. White	....	....	....	....	....	....	....	293.00	52.39	....
	Lease 1, Loc. 50	Western Mining Corporation Ltd.	....	....	....	....	....	....	....	4,151.00	361.62	86.37
		Cancelled leases	....	....	....	....	....	4,585.24	258.74	374,334.92	98,839.10	5,906.27
		Sundry claims and leases	....	....	....	....	....	2.68	110.46	46,838.41	8,650.24	.13

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 1965					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.*										
Kalgoorlie....	G.M.L. 6562E....	Bretvic	....	....	....	....	....	....	....	326.50	26.09	....
	6503E	Coronation	....	....	....	....	....	....	....	20.50	2.52	....
	5510E	Golden Dream	....	....	47.00	6.95	....	....	....	254.75	26.24	....
		Prior to transfer to present holders	....	....	....	....	....	....	....	530.74	149.77	....
	6636E	Golden Cross	....	....	....	....	....	....	....	71.00	4.11	....
	6620E	Golden Goose	....	....	....	....	....	....	....	60.50	2.85	....
	6630E	Golden Star	....	....	1,296.00	44.23	....	....	....	1,296.00	44.23	....
	G.M.L. 6502E	Gold Mines of Kalgoorlie (Aust.) Ltd. (Hannans North Mine)	....	....	363.00	28.02	....	....	....	10,334.75	2,235.53	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	....
		Prior to transfer to present holders	....	....	....	....	....	....	....	51.50	18.22	.57
	6563E, etc.	Gold Mines of Kalgoorlie (Aust.) Ltd. (Mt. Charlotte Mine)	....	....	272,827.00	38,133.27	....	....	....	398,024.00	54,827.05	....
		Prior to transfer to present holders	....	....	....	....	....	....	5.72	85,723.60	18,167.21	171.56
	6589E	Grays Central	....	....	31.00	34.71	....	....	....	875.75	199.78	....
	6091E	Lesanben	....	....	34.75	32.72	....	....	193.96	1,273.05	823.37	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	....
	6639E	Old Hinchcliffe	....	....	218.50	27.91	....	....	....	355.00	51.96	....
	6642E	Olive K	....	....	31.75	8.42	....	....	....	31.75	8.42	....
	5852E, (6024E)	Pedestal Leases	....	....	....	....	....	....	....	1,828.50	490.37	....
	5852E	Pedestal	....	....	92.75	16.99	....	....	....	1,701.50	461.92	....
	(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	....	....	447.84	43.74	.02	232.41	1,124.98	63,845.87	23,477.08	.20
Wombola	5689E, etc.	Haoma Leases	....	....	....	....	....	....	....	6,810.50	7,778.13	1,011.58
		Prior to transfer to present holders	....	....	....	....	....	....	.25	60,201.00	57,932.14	827.18
	5497E, 5500E	Daisy Leases	....	....	1,180.50	933.85	26.04	....	....	21,781.45	19,747.48	884.76
	5497E	Daisy	....	....	....	....	....	....	....	6,282.25	5,031.93	....
	5500E	Happy-go-lucky	....	....	....	....	....	....	....	2,075.25	1,675.85	....
	6635E	Hodad	....	....	78.00	29.21	....	....	....	2,864.00	358.95	49.51
	6487E	Leslie	....	....	....	....	....	....	....	382.25	355.13	.49
	6597E	Leslie North	....	....	....	....	....	....	....	810.00	68.40	13.41
	6614E	Logan's Gold Mine	....	....	120.00	21.59	....	....	....	736.75	131.45	1.25
	5798E	Maranoa	....	....	....	....	....	....	....	563.00	142.62	5.65
		Prior to transfer to present holders	....	....	....	....	....	....	32.17	3,183.50	1,633.27	....
	6533E	Rosemary	....	....	885.75	158.26	....	....	....	9,814.10	9,676.11	121.78
		Voided leases	....	....	....	....	....	3.80	2,498.57	44,374.34	49,768.87	1.21
		Sundry claims	....	....	....	....	....	....	711.10	26,113.43	14,588.86	.20

		From District Generally :—										
		Sundry Parcels treated at :										
		State Battery, Kalgoorlie	....	....	....	*757.31	61.99	....	....	390.70	*38,526.25	458.17
		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	7.18	....	15.00	11.35	....	17,010.90	10,073.32	430.68	7,580.35	....
		Total	**7.18**	....	**2,121,051.09**	**477,792.51**	**163,145.83**	**33,728.72**	**41,186.82**	**87,884,380.94**	**36,491,850.63**	**5,903,926.41**
		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	....
Bulong	G.M.L. 1311Y....	Blue Quartz	....	....	....	....	....	....	....	2,031.25	701.61	....
	1342Y	Rocket	....	....	28.75	25.06	....	....	....	28.75	25.06	....
		Voided leases	....	....	....	....	....	107.54	8,526.12	108,979.05	85,871.31	....
		Sundry claims	....	....	128.00	50.38	....	1,655.86	1,611.58	18,357.23	18,101.37	....
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	....	....	31.50	13.70	....	42.88	154.58	1,958.08	973.48	....
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	....	....	38.25	11.05	....	112.69	51.88	2,694.85	1,060.86	....
Trans Find	....	Voided leases	....	....	....	....	....	....	....	1,098.42	876.22	....
		Sundry claims	....	....	....	....	....	....	5.93	728.25	315.06	....
		From District generally :—										
		Sundry Parcels treated at :										
		Various Works	....	....	....	....	....	....	....	6,102.15	*7,154.95	86.52
		Reported by Banks and Gold Dealers	....	....	....	....	....	25,225.22	70.15	.01	28.44	....
		Total	....	....	**226.50**	**100.19**	....	**27,405.51**	**16,036.77**	**188,357.83**	**132,974.21**	**99.44**

Coolgardie Goldfield.

COOLGARDIE DISTRICT.

Bonnievale	G.M.L. 5986	Jenny Wren	....	....	....	....	....	....	....	401.00	236.05	.29
	5622	Lucky Hit	....	....	....	....	....	....	3.28	1,146.35	676.78	....
	5890	Rayjax	....	....	52.75	70.62	....	....	....	713.50	1,176.89	4.70
	6007	Sabrina	....	....	....	....	....	....	....	38.75	31.34	....
		Voided leases	....	....	....	....	....	....	212.48	362,696.87	196,412.90	19.86
		Sundry claims	....	....	616.00	57.62	....	....	238.91	9,242.13	5,594.64	.87

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 1965					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.*										
Bulla Bulling	6035	Bernguard	....	....	37.50	9.50	....	....	....	37.50	9.50	....
	6003	Worked Out	....	....	....	....	....	....	....	135.75	146.21	....
		Voided leases	....	....	....	....	....	....	....	1,410.56	968.52	....
		Sundry claims	....	3.62	65.75	18.36	....	5.21	19.60	2,134.51	838.02	....
Burbanks	....	Voided leases	....	....	....	....	....	14.90	376.98	420,591.86	306,446.31	521.06
		Sundry claims	....	....	203.75	84.35	....	55.05	497.55	17,684.10	9,364.29	.93
Cave Rocks	....	Voided leases	....	....	....	....	....	....	....	8,223.16	1,941.42	....
		Sundry claims	....	....	28.25	1.89	....	....	50.00	4,816.40	1,114.69	....
Coolgardie	G.M.L. 6026	Cyanide North	....	....	36.25	6.43	....	....	....	36.25	6.43	....
	6032	El Dorado	....	....	....	....	....	....	....	8.00	8.95	....
	5844	Jackpot	....	....	102.00	42.66	....	....	....	10,248.75	4,261.04	....
	5884	Lone Hand	....	....	....	....	....	....	19.85	499.00	84.85	....
	6024	New Cock Shot	.60	....	47.00	16.04	.51	66.05	....	47.00	16.04	.51
		Voided leases	....	....	....	....	....	1,301.71	5,464.54	1,259,542.44	524,008.83	5,730.26
		Sundry claims	....	....	1,092.75	202.29	....	236.14	2,966.48	83,943.19	29,429.43	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	531.20	....
Gibraltar	5723	Lloyd George	....	....	....	....	....	....	....	763.00	176.78	....
		Voided leases	....	....	....	....	....	....	33.97	38,762.63	20,114.27	....
		Sundry claims	....	....	....	....	....	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. 16A, Loc. 59	C.W. Avard	....	....	44.75	21.24	....	....	....	85.00	32.30	....
	P.P.L. 334 Loc. 59	Gold Mines of Kalgoorlie (Aust.) Ltd.	....	....	....	....	....	....	....	3,143.75	1,058.85	....
	P.P.L. 316, Loc. 59; P.P.L. 330, Loc. 59	Gold Mines of Kalgoorlie (Aust.) Ltd.	....	....	738.50	154.50	....	....	....	263,423.00	134,593.67	29,873.27
		Prior to transfer to present holders	....	....	....	....	....	....	....	9,346.75	5,081.22	....
	P.P.L. 482, Loc. 59	T. R. Baker	....	....	121.50	16.42	....	....	....	1,623.50	232.79	.08
	P.P.L. 486, Loc. 59	H. Boucher	....	....	....	....	....	....	....	423.50	96.42	....
	P.P.L. 489, Loc. 59	C. L. Voumard	....	....	....	....	....	....	73.47	77.25	37.77	....
		Cancelled leases	....	....	....	....	....	2.56	486.33	18,631.96	13,296.53	1.10
		Sundry claims and leases	....	....	....	....	....	1.63	132.06	1,957.75	859.58	....

Higginsville	G.M.L. 5647	Fair Play Gold Mine	4.42	....	....	....	....	4.42	62.70	28,676.75	3,195.11	.02
		Voided leases	....	....	....	....	....	....	482.47	46,410.85	22,314.61	160.80
		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	....	....	42.00	1.43	....	....	....	517.50	65.91	....
		Voided leases	....	....	....	....	....	....	11.09	106,660.81	26,931.68	....
		Sundry claims	....	418.77	65.25	60.87	....	6.88	551.62	3,450.35	1,116.83	....
Londonderry	....	Voided leases	....	....	....	....	....	....	95.04	34,155.35	22,238.37	.35
		Sundry claims	....	....	....	....	....	16.68	80.78	4,241.92	2,688.82	22.42
Mungari	....	Voided leases	....	....	....	....	....	....	17.71	1,872.50	458.43	....
		Sundry claims	....	....	160.75	8.67	....	1.77	153.24	3,243.44	781.26	....
Paris	G.M.L. 5953, etc.	Paris Gold Mines Pty. Ltd.	....	....	....	620.35	1,716.22	....	....	42,516.00	14,808.24	17,015.61
	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	....
Ryan's Find	5999	Little Nipper	....	2,019.84	26.75	662.77	....	....	3,126.84	92.25	1,104.04	....
		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	....	....	....	....	*6.87	....	....	....	771.01	*41,379.11	17.73
	Various Works	....	....	....	....	....	....	7.75	....	4,375.61	*33,855.21	473.96
	Reported by Banks and Gold Dealers	....	2.84	1.20	....	....	....	15,002.12	743.46	48.25	141.36	1.05
		Total	**7.86**	**2,443.43**	**3,481.50**	**2,062.88**	**1,716.73**	**17,130.07**	**21,800.34**	**2,996,419.85**	**1,538,801.10**	**54,414.07**

KUNANALLING DISTRICT.

Carbine	G.M.L. 1048S....	Carbine	....	....	....	....	....	....	....	33.50	17.79	....
		Voided leases	....	....	....	....	....	....	687.98	85,927.86	52,381.02	....
		Sundry claims	....	....	20.25	2.97	....	136.27	96.96	6,689.38	2,371.86	....
Chadwin	....	Voided leases	....	....	....	....	....	....	....	4,837.80	5,298.69	2.50
		Sundry claims	....	....	....	....	....	14.28	82.36	5,987.55	2,953.07	.25

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 1965					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. KUNANALLING DISTRICT — continued.										
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	....	....	....	....	....	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	....	....	139.50	28.17	....	111.91	102.70	5,083.28	2,630.51	....
Kunanalling	G.M.L. 1052S....	Catherwood	....	....	....	....	....	....	....	234.50	10.44	....
		Voided leases	....	....	....	....	....	86.13	1,734.92	130,303.61	100,812.73	40.77
		Sundry claims	....	....	304.25	82.25	6.39	216.53	976.87	16,872.02	10,261.16	21.67
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	....	....	**464.00**	**113.39**	**6.39**	**1,520.70**	**5,799.52**	**366,201.95**	**253,631.00**	**773.06**
		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)			17.25	351.84	58.28	....	....	3,319,872.25	457,885.54	126,971.82
		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	....	....	22.50	48.93	5.41	8.47	45.49	7,639.39	4,214.91	20.34
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	....	....	10.25	1.06	....	4.98	....	648.60	160.61	....

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	....	....	592.00	615.12	118.69	....	2.70	46,599.80	66,874.97	2,002.82
		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	....	....	48.25	11.12	.48	.46	4.27	3,200.83	843.70	5.76
Holleton	G.M.L. 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
Hope's Hill	....	Voided leases	....	....	....	....	....	....	74.78	314,609.67	63,028.26	4,364.45
		Sundry claims	....	.36	93.35	6.60	.39	21.12	96.11	4,801.62	1,470.21	1.59
Kennyville	3875	Victoria	....	....	....	....	....	....	....	5,458.00	1,206.32	2.12
		Voided leases	....	....	....	....	....	....	18.76	55,876.63	21,625.66	.59
		Sundry claims	....	....	8.50	5.44	.11	....	5.06	8,729.00	2,352.28	.56
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	Cornwall	....	....	21.25	1.89	.09	....	....	17,790.25	2,466.84	528.00
	4039	Cromwell	....	....	....	....	....	....	....	1,069.50	164.51	.07
	3942, etc.	Edwards Reward Leases	....	....	....	....	....	....	....	75,726.75	32,480.80	399.11
		Prior to transfer to present holders		....	....	....	....	....	....	5,946.00	4,401.11	....
	4034	Firelight	....	....	....	....	....	....	2.68	6,695.75	943.52	.15
	3724	Francis Firness	....	14.48	1,253.50	494.59	47.27	....	512.87	21,673.75	9,679.45	255.55
	4230	May Queen	....	....	....	....	....	....	....	286.00	43.42	....
	(3970)	Mountain Queen	....	....	85.00	3.93	.23	....	....	1,456.50	482.36	2.22
	4035	Undaunted	....	....	56.00	3.47	.03	....	....	994.50	122.77	.10
		Voided leases	....	....	....	....	....	....	1,546.04	1,214,713.83	278,207.95	16,051.34
		Sundry claims	....	....	59.50	11.71	.61	11.35	809.31	38,600.09	13,902.78	85.37
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
		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
	4461	Marjorie Glen Reward	....	....	....	....	....	....	191.46	3,210.55	4,047.72	4.85
		Voided leases	....	....	....	....	....	3.84	5.20	6,991.87	1,350.36	24.55
		Sundry claims	....	....	....	....	....	....	1.85	771.00	956.57	....
Parkers Range	4508	Buffalo	....	....	284.50	54.74	.74	....	....	617.75	119.64	3.70
	4512	Constance Una	....	....	108.50	107.78	4.08	....	....	376.00	466.06	28.65
		Voided leases	....	....	....	....	....	.42	270.76	64,082.85	32,812.23	27.43
		Sundry claims	....	....	96.25	3.78	.18	6.59	303.93	13,755.80	5,652.46	2.45
Southern Cross	G.M.L. 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	....	....	....	....	....	95.90	648.99	8,648.41	2,747.28	7.90

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 1965					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										
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 Goldfield Generally :—											
	Sundry parcels treated at :											
		State Battery, Marvel Loch	....	....	....	*500.90	11.50	....	....	89.00	*3,154.25	14.56
		Various Works	....	....	....	....	....	....	....	624.73	*117,106.07	820.41
		Reported by Banks and Gold Dealers	....	....	....	....	....	325.29	81.41	.60	170.54	....
		Total	....	**14.84**	**2,756.60**	**2,222.90**	**248.09**	**2,198.76**	**6,322.03**	**8,282,403.12**	**2,437,341.20**	**213,537.09**
		Dundas Goldfield.										
Beete	(1907)	Eldridges Find	....	....	61.00	39.86	3.17	....	....	1,804.00	1,318.09	66.10
		Voided leases	....	....	....	....	....	....	....	694.50	530.89	22.99
		Sundry claims	....	....	30.00	16.46	....	....	....	416.50	392.87	....
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
Norseman	1288, etc.	Central Norseman Gold Corporation N.L.	....	....	182,589.00	95,114.45	62,654.30	....	....	3,960,738.20	1,853,062.66	1,197,382.74
		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	.16	5.74	34.00	7.74	2.19	1,052.25	3,523.62	49,779.45	22,638.38	228.00
Peninsula	....	Voided leases	....	....	....	....	....	....	24.29	9,603.39	6,102.61	12.20
		Sundry claims	....	....	....	....	....	....	....	217.25	119.32	.97
	From Goldfields Generally :—											
	Sundry parcels treated at :											
		State Battery, Norseman	....	....	....	*204.97	14.45	....	....	427.89	*25,713.85	1,069.45
		Various Works	....	....	....	....	....	....	54.52	1,029.89	*15,124.31	2,588.91
		Reported by Banks and Gold Dealers	3.58	....	....	....	.34	1,186.36	49.59	47.50	21.37	1.04
		Total	**3.74**	**5.74**	**182,714.00**	**95,383.48**	**62,674.45**	**2,255.52**	**16,400.63**	**6,007,087.12**	**2,824,982.77**	**1,615,246.57**
		Phillips River Goldfield.										
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	6,891.59
		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.	....	....	....	§1,063.83	3,136.36	....	....	....	§15,345.84	45,089.37
		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 Goldfield 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	....	....	....	**1,063.83**	**3,136.36**	**607.11**	**823.32**	**130,659.24**	**119,420.47**	**61,232.45**

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	....	....	....	....	....	....	.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	....	Voided leases	....	....	....	....	....	....	....	294.00	154.39	....
		Sundry claims	....	....	....	....	....	....	....	81.75	81.44	....
Ongerup	G.M.L. 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	....	....	....	....	....	**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	2.98	1.14	....	....	....	1,194.95	1,111.85	....	967.53	1,140.93
		Total	**2.98**	**1.14**	....	....	....	**1,194.95**	**1,111.85**	**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 1965.

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	....	....	....	....	....	....	....	....	11.11	....	....	11.11	....
West Kimberley	....	....	....	....	....	....	....	....	....	....	....	....	7,965.82
West Pilbara	....	....	....	....	....	....	....	....	....	....	....	....	....
Pilbara	Marble Bar	5.60	....	852.00	492.14	497.74	10.14	8.18	....	920.00	499.87	508.05	10.14
	Nullagine	2.58	....	68.00	7.73	10.31	....						
Ashburton	....	....	....	....	....	....	....	....	....	....	....	....	....
Gascoyne	....	....	....	....	....	....	....	....	....	98.00	260.11	260.11	11.34
Peak Hill	....	....	....	....	....	....	....	....	52.57	1,304.00	48.35	100.92	3.40
East Murchison	Lawlers	.13	....	2,026.50	1,238.52	1,238.65	30.68						
	Wiluna	....	....	....	4.78	4.78	1.58	.13	....	2,026.50	1,243.30	1,243.43	32.26
	Black Range	....	....	....	....	....	....						
Murchison	Cue	....	....	528.50	162.82	162.82	74.23						
	Meekatharra	50.76	239.11	2,808.25	678.15	968.02	33.07	87.70	239.11	168,226.50	55,150.36	55,477.17	4,310.16
	Day Dawn	36.11	....	58.25	21.82	57.93	5.20						
	Mt. Magnet	.83	....	164,831.50	54,287.57	54,288.40	4,197.66						
Yalgoo	....	....	....	....	....	....	....	....	.81	....	....	.81	....
Mt. Margaret	Mount Morgans	3.64	....	79.00	37.22	40.86	.60						
	Mount Malcolm	....	....	1,134.50	211.69	211.69	8.26	7.63	....	1,213.50	248.91	256.54	8.86
	Mt. Margaret	3.99	....	....	....	3.99	....						
North Coolgardie	Menzies	2.87	2.50	28,128.55	13,205.78	13,211.15	2,054.62						
	Ularring	....	....	764.00	450.28	450.28	5.63	3.17	2.50	29,387.05	13,874.04	13,879.71	2,071.82
	Niagara	....	....	158.50	64.64	64.64	....						
	Yerilla	.30	....	336.00	153.34	153.64	11.57						
Broad Arrow	....	....	....	....	....	....	....	2.01	9.53	15,635.13	3,044.40	3,055.94	37.52
North-East Coolgardie	Kanowna	4.43	....	457.00	262.12	266.55	2.64	5.06	....	661.00	330.34	335.40	2.64
	Kurnalpi	.63	....	204.00	68.22	68.85	....						
East Coolgardie	East Coolgardie	7.18	....	2,121,051.09	447,792.51	477,799.69	163,145.83	7.18	....	2,121,277.59	477,892.70	477,899.88	163,145.83
	Bulong	....	....	226.50	100.19	100.19	....						
Coolgardie	Coolgardie	7.86	2,443.43	3,481.50	2,062.88	4,514.17	1,716.73	7.86	2,443.43	3,945.50	2,176.27	4,627.56	1,723.12
	Kunanalling	....	....	464.00	113.39	113.39	6.39						
Yilgarn	....	....	....	....	....	....	....	....	14.84	2,756.60	2,222.90	2,237.74	248.09
Dundas	....	....	....	....	....	....	....	3.74	5.74	182,714.00	95,383.48	95,392.96	62,674.45
Phillips River	....	....	....	....	....	....	....	....	....	....	1,063.83	1,063.83	3,136.36
South-West Mineral Field	....	....	....	....	....	....	....	....	....	....	....	....	....
Northampton Mineral Field	....	....	....	....	....	....	....	....	....	....	....	....	....
State Generally	....	....	....	....	....	....	....	2.98	1.14	....	....	4.12	....
Outside Proclaimed Goldfield	....	....	....	....	....	....	....	....	....	....	....	....	....
Total	....	....	....	....	....	....	....	**135.64**	**2,780.78**	**2,530,165.37**	**653,438.86**	**656,355.28**	**245,381.81**

TABLE III

Return showing total production reported to the Mines Department, and respective Districts and Goldfields from whence derived, to 31st December, 1965.

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	3,027.46	22,931.90	17,281.87	29,389.01	128.76
West Kimberley	....	....	....	....	....	....	....	1.30	24.68	1.00	2.49	28.47	33,197.57
West Pilbara	....	....	....	....	....	....	....	6,339.37	374.74	24,900.96	24,317.02	31,031.13	1,910.66
Pilbara	Marble Bar	15,510.47	4,569.14	343,705.72	331,765.57	351,845.18	33,002.76	26,020.00	7,478.83	493,748.14	467,222.78	500,721.61	34,083.55
	Nullagine	10,509.53	2,909.69	150,042.42	135,457.21	148,876.43	1,080.79						
Ashburton	....	....	....	....	....	....	....	9,268.52	482.46	6,807.10	2,913.43	12,664.41	41,971.38
Gascoyne	....	....	....	....	....	....	....	698.49	121.33	1,042.75	2,183.27	3,003.09	70.93
Peak Hill	....	....	....	....	....	....	....	3,387.79	5,371.79	783,070.73	322,738.34	331,497.92	3,793.90
East Murchison	Lawlers	7,103.51	2,343.19	2,017,119.67	825,469.51	834,916.21	27,261.15						
	Wiluna	236.48	1,254.11	8,873,649.69	1,872,319.97	1,873,810.56	10,322.32	9,010.95	22,207.27	12,622,225.83	3,653,035.85	3,684,254.07	60,307.63
	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	6,815,391.31	1,402,653.25	1,416,882.55	274,758.99						
	Meekatharra	14,700.99	18,499.14	2,317,370.06	1,310,467.93	1,343,668.06	5,267.35	25,752.60	59,413.68	14,701,429.62	5,856,059.52	5,941,225.80	509,176.83
	Day Dawn	3,291.17	11,341.80	2,037,595.63	1,375,641.81	1,390,274.78	169,447.42						
	Mt. Magnet	2,636.13	20,467.75	3,531,072.62	1,767,296.53	1,790,400.41	59,703.07						
Yalgoo	....	....	....	....	....	....	....	1,808.77	3,224.00	443,349.58	264,036.39	269,069.16	1,522.41
Mt. Margaret	Mt. Morgans	3,574.87	9,401.98	1,217,999.31	717,985.31	730,962.16	5,831.33						
	Mt. Malcolm	4,066.98	16,668.99	7,752,932.47	3,069,645.37	3,090,381.34	190,781.96	11,789.38	35,425.32	11,499,105.02	4,961,674.24	5,008,888.94	262,803.99
	Mt. Margaret	4,147.53	9,354.35	2,528,173.24	1,174,043.56	1,187,545.44	66,190.70						
North Coolgardie	Menzies	1,696.69	7,032.09	1,918,675.13	1,421,007.60	1,429,736.38	37,228.46						
	Ularring	129.66	7,298.59	535,817.70	446,587.15	454,015.40	22,286.97	4,857.10	19,969.57	3,695,745.13	2,574,516.67	2,599,343.34	70,576.36
	Niagara	1,718.48	1,821.77	944,436.52	528,578.14	532,118.39	5,716.17						
	Yerilla	1,312.27	3,817.12	296,815.78	178,343.78	183,473.17	5,344.76						
Broad Arrow	....	....	....	....	....	....	....	21,992.52	28,005.48	1,403,014.79	749,926.00	799,924.00	5,649.06
North-East Coolgardie	Kanowna	106,543.26	13,526.67	1,010,319.56	627,680.19	747,750.12	3,049.28	119,380.53	21,825.58	1,024,702.63	646,805.31	788,011.42	3,061.99
	Kurnalpi	12,837.27	8,298.91	14,383.07	19,125.12	40,261.30	12.71						
East Coolgardie	East Coolgardie	33,728.72	41,186.82	87,884,380.94	36,491,850.63	36,566,766.17	5,903,926.41	61,134.23	57,223.59	88,072,738.27	36,624,824.84	36,743,182.66	5,904,025.85
	Bulong	27,405.51	16,036.77	188,357.33	132,974.21	176,416.49	99.44						
Coolgardie	Coolgardie	17,130.07	21,800.34	2,996,419.85	1,538,801.10	1,577,731.51	54,414.07	18,650.77	27,599.86	3,362,621.80	1,792,432.10	1,838,682.73	55,187.13
	Kunanalling	1,520.70	5,799.52	366,201.95	253,631.00	260,951.22	773.06						
Yilgarn	....	....	....	....	....	....	....	2,198.76	6,322.03	8,282,403.12	2,437,341.20	2,445,861.99	213,537.09
Dundas	....	....	....	....	....	....	....	2,255.52	16,400.63	6,007,087.12	2,824,982.77	2,843,638.92	1,615,246.57
Phillips River	....	....	....	....	....	....	....	607.11	823.32	130,659.24	119,420.47	120,850.90	61,232.45
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	....	....	....	....	....	....	....	1,194.95	1,111.85	27.00	9,977.28	12,284.08	32,662.66
Outside Proclaimed Goldfield	....	....	....	....	....	....	....	....	....	....	....	....	....
Total	....	....	....	....	....	....	....	**335,741.42**	**316,482.13**	**152,582,333.31**	**63,354,093.94**	**64,006,317.49**	**8,915,347.53**

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	601,674·33	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
1965	2,996·56	656,440·42	659,436·98	10,361,082
	11,597,237·04	53,941,741·42	65,538,978·46	504,843,455

	1964	1965
	£A	£A
Estimated Mint value of above production	492,570,060	500,873,762
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	1,322,711	1,380,091
Estimated Total	£A494,482,373	£A504,843,455
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	5,463,022	6,292,604
Gross estimated value of gold won	£A500,106,843	£A511,297,507

TABLE V.

Quantity and Value of Minerals, other than Gold, Reported during the year 1965

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. 15A	South-West	Western Aluminium N.L.	148,468.00	....	4,454,040.00 (*f*)
		ASBESTOS (Chyrsotile)			
M.C. 98L, etc.	Pilbara	Stubbs, S. H.	372.99	....	28,228.00
L.T.T. 1454H	Pilbara	Hancock, L. G.	29.10	....	611.10
			402.09	....	28,839 10 (*b*)
		ASBESTOS (Crocidolite)			
M.C. 53, etc.	West Pilbara	Australian Blue Asbestos Pty. Ltd....	9,279.94	....	873,039.51 (*b*)
		BARYTES			
M.C. 20N	Murchison	Universal Milling Co. Pty. Ltd.	750.75	....	3,003.10 (*a*)
		BENTONITE (See Clays)			
		BERYL (*g*) (*h*)			
				Be O/units	
M.C. 35	Yalgoo	Todd, Dan	1.86	21.20	218.00
P.A. 2631	Yalgoo	Phillips, E. R.	1.63	17.45	178.90
P.A. 2640	Yalgoo	Phillips, E. R.	4.09	46.19	410.50
M.L. 80, etc.	Coolgardie	Australian Glass Manufacturers Co. Pty. Ltd.	5.50	63.80	638.00
			13.08	148.64	1,445.40 (*b*)
		BUILDING STONE (Granite Facing Stone)			
M.C. 719H	South-West	Crawford Quarries Pty. Ltd.	106.00	....	2,120.00 (*c*)
		BUILDING STONE (Quartz—Dead White)			
M.C. 59	Coolgardie	Lefroy, G.	245.00	....	2,055.00 (*a*)
		BUILDING STONE (Sandstone)			
M.C. 990H	South-West	Caporn, C. A.	48.00	....	144.00
M.C. 1036H	South-West	Caporn, C. A.	173.00	....	519.00
			221.00	....	663.00 (*c*)
		BUILDING STONE (Slate)			
M.C. 1020H	South-West	Gelfi, B. J.	185.00	....	757.50 (*c*)
		BUILDING STONE (Spongolite)			
Q.A. 1, etc.	Phillips River	Frayne, W. L.	529.00	....	2,393.00 (*c*)
		CLAYS (Bentonite)			
M.C. 282H, etc.	South-West	Collins, A. C.	391.45	....	978.65
M.C. 1042H, etc.	South-West	Noonan, A. J.	30.00	....	90.00
M.C. 907H, etc.	South-West	Universal Milling Co. Pty. Ltd.	500.00	....	750.00
			921.45	....	1,818.65 (*a*)
		CLAYS (Cement Clay)			
M.C. 492H, etc.	South-West	Cockburn Cement Pty. Ltd.	21,489.00	....	26,861.25
M.C 1019H, etc.	South-West	Bell Bros. Pty. Ltd.	4,500.00	....	2,419.25
			25,989.00	....	29,280.50 (*c*)

(17)—25843

TABLE V.—*Quantity and Value of Minerals, other than Gold, Reported during the Year* 1965—*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. 522H	South-West	Bridge, J. S. & T. D.	5,326.00	....	7,500.80
M.C. 304H	South-West	Clackline Refractories Ltd.	3,263.00	....	3,263.00
M.C. 685H	South-West	Kargotich Bros.	2,000.00	....	1,400.00
M.C. 732H	South-West	Midland Brick Co. Pty. Ltd.	30,833.00	....	15,416.50
Private Property	South-West	†Unspecified Producers	19,680.00	....	14,587.00
			61,102.00	....	42,167.30 (c)
		† From Private Property not held under the Mining Act.			
		CLAYS (Fuller's Earth)			
M.C. 452H	South-West	Read, D. J. & T. I.	63.00	....	(a) 267.25
		CLAYS (Kaolin)			
M.C. 247H	South-West	Universal Milling Co. Pty. Ltd.	190.50	....	(a) 482.60
		CLAYS (White Clay—Ball Clay)			
M.C. 19E	East Coolgardie	Gardner, J. A.	54.00	....	162.00
M.C. 109H	South-West	H. L. Brisbane & Wunderlich Ltd.	1,386.00	....	5,544.00
			1,440.00	....	(c) 5,706.00
		CLAYS (Brick, Pipe and Tile Clays)*			
M.C. 789H	South-West	Peters, O. V. & M. E.	3,750.00	....	4,687.50
Private Property	South-West	Stoneware Pipe and Tiles Pty. Ltd.	9,363.00	....	9,363.00
Private Property	South-West	Stoneware Pipe and Tiles Pty. Ltd.	5,075.00	....	5,075.00
Private Property	South-West	Stoneware Pipe and Tiles Pty. Ltd.	2,060.00	....	2,781.00
Private Property	South-West	Stoneware Pipe and Tiles Pty. Ltd.	31.00	....	31.00
Private Property	South-West	Swaby, F. W.	44,745.00	....	55,931.25
Private Property	South-West	†Unspecified Producers	70,372.00	....	17,852.00
			135,396.00	....	95,720.75 (c)
	* Incomplete.	† From Private Property not held under the Mining Act.			
		COAL			
C.M.L. 448, etc.	Collie	Griffin Coal Mining Co. Ltd.	534,946.50	....	859,472.20
C.M.L. 437, etc.	Collie	Western Collieries Ltd.	458,794.30	....	1,345,514.00
			993,740.80	....	2,204,986.20 (e)
		COPPER ORE & CONCENTRATES (g) (h)		Copper Units	
M.C. 35, etc.	Phillips River	Ravensthorpe Copper Mines N.L.	2,051.50	46,518.00	127,460.10 (b)
		Gold and Silver Content transferred to respective items.			
		CUPREOUS ORE AND CONCENTRATES (Fertiliser)		Av. Assay Cu. %	
P.A. 2730	Pilbara	Wilson, L. T.	3.40	17.80	154.90
M.C. 806	Pilbara	Otway, R. H.....	5.28	13.50	179.95
M.C. 824	Pilbara	Otway, C. A.	4.01	12.40	118.05
M.C. 382L	Pilbara	Henderson, J. M., J. R., C. B.	12.79	12.70	370.80
P.A. 879L	Pilbara	Criddle, J. E.	2.10	35.00	245.30
Crown Lands	Pilbara	Sundry Persons	1.03	41.00	145.00
M.L. 259	West Pilbara	Lee, T.	138.16	18.95	7,062.20
M.C. 63	Ashburton	Rose, W.	15.65	5.20	101.75
P.A. 352	Ashburton	Bennett, C. W., and A.	2.04	12.60	70.50
P.A. 3760	Murchison	Bozanich, L. R.	18.71	15.10	233.95
P.A. 3587N	Murchison	Lorne, N.	9.18	9.00	144.55
M.C. 15	East Murchison	Alac, M.	10.77	14.10	365.70
M.L. 78P	Peak Hill	Motter, G.	111.07	10.16	2,326.25
M.C. 97P	Peak Hill	Alac, M.	25.25	24.68	2,201.65
M.L. 68P	Peak Hill	Thaduna Copper Mines N.L.	(i) 504.00	14.74	25,308.00
M.C. 65P, etc.	Peak Hill	Lee, R.	(i) 114.50	20.82	8,698.05
P.A. 1684F	Mt. Margaret	Gray, F.	9.15	12.00	243.00
M.C. 36	Coolgardie	Horan, T. J.	65.84	8.98	1,086.45
Temp. Res. 2104H	Outside Proclaimed	United Aborigines Mission	25.83	10.51	560.80
			1,078.76	14.92	49,616.85 (a) (b)
		FELSPAR			
M.C. 80, etc.	Coolgardie	Australian Glass Manufacturers Co. Pty. Ltd.	1,384.00	....	9,744.15 (a)

FULLER'S EARTH (See Clays)

TABLE V.—*Quantity and Value of Minerals, other than Gold, Reported during the Year 1965—continued*

Number of Lease, Claim or Area	Goldfield or Mineral Field	Registered Name of Producer	Quantity Long Tons	Metallic Content	Value £A
		GLASS SAND			
M.C. 417H, etc.	South-West	Australian Glass Manufacturers Co. Pty. Ltd.	9,180.00	....	5,965.75
M.C. 285H, etc.	South-West	Leach, R. J.	79.00	....	118.50
			9,259.00	....	(c) 6,084.25
		GYPSUM			
M.C. 30, etc.	Yilgarn	Ajax Plaster Co. Pty. Ltd.	13,720.00	....	11,388.00
M.C. 51, etc.	Yilgarn	H. B. Brady Co. Pty. Ltd.	11,810.00	....	14,762.50
M.C. 9, etc.	Yilgarn	West Australian Plaster Mills Pty. Ltd.	14,861.00	....	10,774.75
M.C. 12, etc.	Dundas	McDonald and Whitfield	200.00	....	100.00
M.C. 612H, etc.	South-West	Hewitt, B.	4,191.00	....	5,713.00
M.C. 485H, etc.	South-West	Swan Portland Cement Ltd.	1,793.00	....	1,720.00
M.C. 881H	South-West	Dooka Gypsum Co.	32.00	....	118.75
			46,607.00	....	44,577.00 (a)

Plaster of Paris reported as manufactured during the year being 21,739.00 tons from 31,036 tons of Gypsum by five Companies. Gypsum used in the manufacture of Cement = 12,501.00 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)	Pig Iron Recovered Tons		
Temp. Res. 1258H	Yilgarn	Charcoal Iron and Steel Industry	40,673.00	....	935,749.00 (c) (d)

Ore treated 65,623.00 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)		Av. Assay Fe%	
M.C. 10, etc.	West Kimberley	Australian Iron and Steel Ltd.	2,240,939.00	64.28	2,222,269.00 (b)
		LEAD ORES AND CONCENTRATES (g) (h)		Lead Content Tons	
Vic. Loc. 1472	Northampton	Mitchell, G. H.	(i) 49.50	34.64	4,326.60
M.C. 42	Northampton	Camp & Party	(i) 170.53	126.38	16,595.80
M.L. 234	Northampton	Bridson, T. A.	(i) 204.81	150.91	19,059.15
Vic. Loc. 436	Northampton	Hernesniemi, D.	(i) 23.12	13.95	1,305.15
M.L. 284	Northampton	Nooka Syndicate	(i) 773.50	545.98	61,333.30
M.C. 45	Northampton	Camp & Party	(i) 7.21	5.17	542.25
M.C. 43	Northampton	Camp & Party	(i) 1.97	1.20	113.60
Vic. Loc. 2366	Northampton	Camp & Party	(i) 9.52	5.81	548.70
M.C. 48	Northampton	Heinsen, E. H. & Thomas, A. J.	(i) 8.21	4.57	417.60
L.T.T. 1563H	Northampton	Mitchell, E. H.	(i) 5.52	3.84	385.65
			1,253.89	892.45	104,627.80 (b)
		LEAD/ZINC ORES AND CONCENTRATES (g) (h)		Lead Content Tons	
M.C. 29	West Kimberley	Devonian Pty. Ltd.	*3,624.04	486.56	91,691.90 (b)
		* Silver content transferred to Silver Item.	....	Zinc Content Tons 1,010.16	....
		*LIMESTONE (For Building, Burning and Cement making purposes, etc.)			
M.C. 727H	South-West	Thiess Bros. Pty. Ltd.	11,559.00	....	1,733.50
M.C. 684H, etc.	South-West	Bell Bros. Pty. Ltd.	12,349.00	....	15,436.25
M.C. 989H	South-West	Cassella, S.; Cassella, M. & Ioppolo, G. J.	5,939.00	....	7,423.75
M.C. 692H, etc.	South-West	Franconi, D. & S.	3,022.00	....	4,320.00
M.C. 532H	South-West	Gibbs, C. E. & A. J.	1,545.00	....	1,931.25
M.C. 575H, etc.	South-West	Susac, F. & Y.	3,120.00	....	3,900.00
M.C. 709H	South-West	Snader, R.	18.00	....	22.50
M.C. 1071H	South-West	Multari, N.	1,408.00	....	2,112.00
M.C. 1071H	South-West	Koot, J. N.	3,451.00	....	1,107.00
M.C. 1093H	South-West	Multari, N.	230.00	....	345.00
Private Property	South-West	†Unspecified Producers	522,662.00	....	274,670.00
			565,303.00	....	313,001.25 (c)

* Incomplete. † From Private Property not held under the Mining Act.

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
		* LIMESTONE (For Agricultural purposes)			
M.C. 50	Dundas	Esperance Lime Supply	158.00	....	316.00
M.C. 723H	South-West	Plozza, C. W. & W. A.	369.00	....	369.00
			527.00	....	(c) 685.00
		* Incomplete.			
		LITHIUM ORES (Petalite)			
				Li2o Units	
M.L. 80, etc.	Coolgardie	Australian Glass Manufacturers Co. Pty. Ltd.	310.00	1,302.00	2,370.60 (a)
		MAGNESITE			
M.C. 76, etc.	Phillips River	Magnesite (W.A.) Pty. Ltd.	199.08	....	1,588.20 (a) (b)
		MANGANESE (Metallurgical Grade) (g)			
				Av. Assay Mn%	
M.C. 268, etc.	Pilbara	Mt. Sydney Manganese Pty. Ltd.	54,972.89	50.97	619,999.55
M.C. 244L, etc.	Pilbara	Westralian Ores Pty. Ltd.	9,926.00	51.53	114,727.00
M.C. 194L, etc.	Pilbara	D.F.D. Rhodes Pty. Ltd.	1,375.00	44.89	8,134.85
M.C. 292L	Pilbara	Hancock Prospecting Pty. Ltd.	880.32	44.20	5,053.55
M.C. 30P, etc.	Peak Hill	Broken Hill Pty. Co. Ltd.....	29,516.99	48.03	295,169.90
M.C. 24P, etc.	Peak Hill	Westralian Ores Pty. Ltd.	3,498.00	43.20	32,531.00
			100,169.20	49.74	1,075,615.85 (b)
		MANGANESE (Low Grade)			
				Av. Assay Mn%	
M.C. 24P, etc.	Peak Hill	Westralian Ores Pty. Ltd.	39.00	not known	310.05 (a)
		MINERAL BEACH SANDS (Ilmenite) (g)			
				Av. Assay Ti02%	
D.C. 56H, etc.....	South-West	Cable (1956) Ltd.	49,261.66	55.32	See Footnote
D.C. 13H, etc.....	South-West	Ilmenite Pty. Ltd.	34,712.00	53.58	
M.L. 389H, etc.	South-West	Western Mineral Sands Pty. Ltd.	91,679.00	53.69	
M.C. 619, etc.	South-West	Westralian Oil Ltd.	69,826.00	59.76	
M.C. 516H, etc.	South-West	Western Titanium N.L.	147,412.56	54.29	
			392,891.22	55.19	1,926,188.25 (b)
	Footnote : Current values for separate Companies not available for publication.				
		MINERAL BEACH SANDS (Monazite) (g) (h)			
				Th02 Units	
D.C. 56H, etc.....	South-West	Cable (1956) Ltd.	1.00	6.50	60.00
M.C. 619H, etc.	South-West	Westralian Oil Ltd.	547.00	3,598.98	26,025.00
M.C. 516H, etc.	South-West	Westralian Titanium N.L.	520.00	3,447.00	26,065.65
			1,068.00	7,052.48	52,150.65 (b)
		MINERAL BEACH SANDS (Rutile) (g) (h)			
				Ti02 Tons	
M.C. 516H	South-West	Western Titanium N.L.	225.00	215.63	(b) 7,994.40
		MINERAL BEACH SANDS (Leucoxene) (g) (h)			
				Ti02 Tons	
M.C. 619H, etc.	South-West	Westralian Oil Ltd.	105.00	79.90	2,376.00
M.C. 516H, etc.	South-West	Western Titanium N.L.	379.00	337.15	8,429.80
			484.00	417.05	10,805.80 (b)
		MINERAL BEACH SANDS (Zircon) (g) (h)			
				Zr02 Tons	
D.C. 56H, etc....	South-West	Cable (1956) Ltd.	2,697.18	1,763.52	59,379.80
M.C. 619H, etc.	South-West	Westralian Oil Ltd.	12,755.00	8,323.44	171,732.00
M.C. 516H, etc.	South-West	Western Titanium N.L.	12,427.49	8,176.17	144,022.30
			27,879.67	18,263.13	375,134.10 (b)

TABLE V.—*Quantity and Value of Minerals, other than Gold, Reported during the Year 1965—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	Murchison	Universal Milling Co. Pty. Ltd.	186.65	....	1,119.90 (a)
		PETALITE (See Lithium Ores)			
		PHOSPHATIC GUANO			
M.C. 714H	South-West	Ward, R. J.	15.00	....	150.00 (c)
		PYRITES ORE AND CONCENTRATES (For Sulphur) (g) (h)			
				Sulphur Content Tons	
G.M.L. 5715E, etc.	East Coolgardie	Gold Mines of Kalgoorlie (Aust.) Ltd.	22,274.94	7,267.97	90,849.83
G.M.L. 1460, etc.	Dundas	Norseman Gold Mines N.L.	(i) (j) (i)36,905.00	17,596.73	293,272.00
			59,179.94	24,864.70	384,121.83
		SILVER			
			Fine Oz.		
		By-Product Gold Mining	279,520.50	....	163,737.05
		By-Product Copper Mining	3,136.36	....	4,669.90
		By-Product Lead Mining	7,965.82	....	1,798.65
			290,622.68	....	170,205.60
		TALC			
Private Property	South-West	Three Springs Talc Pty. Ltd.	7,087.79	....	102,705.00 (b) (c)
		TANTO/COLUMBITE ORES AND CONCENTRATES (g) (h)			
				Ta205 Units	
M.C. 107	Pilbara	Wilson, L. J.	.15	7.92	272.75
Crown Lands	Pilbara	Sundry Persons	.10	3.64	59.50
M.C. 27	Yalgoo	Todd, Dan	.18	11.88	418.00
M.C. 27	Yalgoo	D. E. Gray and Party	2.20	130.53	4,211.15
M.C. 40	Yalgoo	Armstrong, A.	.06	3.87	118.85
M.C. 35	Yalgoo	Todd, Dan	.30	11.93	391.00
M.L. 647, etc.	Greenbushes	Vultan Syndicate	(k) 6.88	237.19	3,402.00
			9.87	406.96	8,873.25
		TIN (g) (h)			
				Tons	
D.C. 53, etc.	Pilbara	Cooglegong Tin Pty. Ltd.	207.67	143.57	240,737.65
D.C. 201, etc.	Pilbara	Pilbara Tin Pty. Ltd.	138.55	94.61	159,651.70
D.C. 254, etc.	Pilbara	J. A. Johnston & Sons Pty. Ltd.	114.92	82.76	137,900.25
D.C. 276, etc.	Pilbara	D.D. Mining Co.	27.70	18.82	31,658.45
D.C. 16, etc.	Pilbara	Leonard, H. V.	85.41	58.76	96,271.85
D.C. 354, etc.	Pilbara	Edwards, M. R.	38.79	25.44	41,961.10
P.A. 2733	Pilbara	Gordon, R. F. and G. N.	.50	.33	507.80
D.C. 305	Pilbara	Russell, H. H.	.70	.48	823.35
D.C. 474	Pilbara	Dorrington, A. W.	.25	.18	259.55
M.C. 745	Pilbara	Gordon, G. N. and Turbett, D. A.	1.12	.76	1,322.45
P.A. 2750	Pilbara	Mallet, G. and Billing, R. J.	.11	.05	87.65
D.C. 281, etc.	Pilbara	J. A. Johnston & Sons Pty. Ltd.	.78	.50	821.65
M.C. 109	Pilbara	McLeod, D. W.	.51	.34	594.10
D.C. 497	Pilbara	J. M. Henderson & Sons	2.41	1.75	2,958.95
M.C. 653	Pilbara	Flegg, H. N.	.32	.21	340.35
D.C. 258	Pilbara	Cassella, R. B. and Rose, K.	.73	.45	742.00
P.A. 2751	Pilbara	McLeod, D. W.	.25	.18	302.40
Crown Lands	Pilbara	Sundry Persons	22.43	15.77	24,211.30
P.A. 312, etc.	West Pilbara	Nomads Pty. Ltd.	2.48	1.73	3,002.25
M.C. 42	Yalgoo	Todd, Dan	.07	.04	52.85
M.C. 30	Coolgardie	Binnerinjie Tin Syndicate	.14	.08	109.25
M.L. 647, etc.	Greenbushes	Vultan Syndicate	29.68	21.42	33,877.25
Crown Lands	Greenbushes	Sundry Persons	.06	.04	62.70
			675.58	468.27	778,256.85

(*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 period under review. (*h*) Metallic content calculated on assay basis. (*i*) Concentrates. (*j*) By-Product Gold mining. (*k*) By-Product Tin mining. (*l*) Crude ore only.

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 1956 TO 1965 INCLUSIVE.‡

COMPANY	1956			1957			1958			1959			1960		
	Above	Under	Total	Above	Under	Total	Above	Under	Total	Above	Under	Total	Above	Under	Total
†Boulder Perseverance, Ltd.	181	113	294	....	....	....	....	....	....	....	....	....	....	....	....
Central Norseman Gold Corporation N.L.	159	209	368	165	226	391	166	232	398	173	214	387	169	209	378
Eclipse Gold Mines N.L.	....	....	....	....	....	....	27	8	35	17	10	27	17	15	32
Golden Horseshoe (New) Ltd.	35	....	35	6	....	6	....	....	....	....	....	....	....	....	....
Gold Mines of Kalgoorlie (Aust.) Ltd. (Boulder)	228	223	451	417	500	917	392	538	930	374	455	829	375	446	821
Great Boulder G.Ms. Ltd.	349	380	729	330	400	730	323	387	710	308	399	707	290	385	675
*Great Western Consolidated	232	270	502	220	223	443	220	241	461	207	218	425	197	174	371
Hill 50 Gold Mine N.L.	98	85	183	108	94	202	103	103	206	95	88	183	97	87	184
†Kalgoorlie Enterprise Ltd.	8	100	108	....	....	....	....	....	....	....	....	....	....	....	....
§Kalgurli Ore Treatment Co. Ltd.	40	....	40	33	....	33	28	....	28	....	....	....	....	....	....
Lake View and Star Ltd.	471	523	994	460	517	977	433	525	958	451	535	986	432	513	945
Moonlight Wiluna Gold Mines Ltd. (Timoni)	37	32	69	36	31	67	35	31	66	31	27	58	31	24	55
Gold Mines of Kalgoorlie (Aust.) Ltd. (Mt. Charlotte)	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
North Kalgurli (1912) Ltd.	156	239	395	158	250	408	163	263	426	181	251	432	181	249	430
Paris Gold Mines Pty Ltd.	....	....	....	....	....	....	....	....	....	6	4	10	15	11	26
Gold Mines of Kalgoorlie (Aust.) Ltd. (Barbara and Bayleys Leases)	37	73	110	34	61	95	23	48	71	19	36	55	18	37	55
New Coolgardie Gold Mines N.L.' Callion Leases)	3	11	14	....	....	....	....	....	....	....	....	....	....	....	....
Radio Gold Mines	6	6	12	7	7	14	6	6	12	6	6	12	6	6	12
†South Kalgurli Consolidated	13	84	97	....	....	....	....	....	....	....	....	....	....	....	....
Sons of Gwalia Ltd.	105	156	261	107	146	253	109	142	251	99	137	236	106	139	245
Sunshine Reward Amalgamated Leases	8	7	15	2	....	2	8	3	11	5	2	7	3	1	4
All other Operators	544	407	951	498	349	847	476	313	789	521	398	919	469	290	759
State Average (inc. Diggers)	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

COMPANY	1961			1962			1963			1964			1965		
	Above	Under	Total	Above	Under	Total	Above	Under	Total	Above	Under	Total	Above	Under	Total
†Boulder Perseverance, Ltd.	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Central Norseman Gold Corporation N.L.	163	220	383	151	213	364	151	208	359	157	181	338	156	148	304
Eclipse Gold Mines N.L.	18	13	31	16	9	25	13	6	19	2	4	6	....	....	....
Golden Horseshoe (New) Ltd.	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Gold Mines of Kalgoorlie (Aust.) Ltd. (Boulder)	374	430	804	379	436	815	426	449	875	378	379	757	355	363	718
Great Boulder G.Ms. Ltd.	296	385	681	300	369	669	307	378	685	306	381	687	291	360	651
*Great Western Consolidated	164	124	288	144	92	236	58	28	86	16	....	16	7	....	7
Hill 50 Gold Mine N.L.	97	93	190	99	110	209	98	130	228	100	143	243	91	113	204
†Kalgoorlie Enterprise Ltd.	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
§Kalgurli Ore Treatment Co. Ltd.	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Lake View and Star Ltd.	417	514	931	411	527	938	417	545	962	393	520	913	370	483	853
Moonlight Wiluna Gold Mines Ltd. (Timoni)	30	30	60	33	39	72	35	38	73	35	31	66	32	36	68
Gold Mines of Kalgoorlie (Aust.) Ltd. (Mt. Charlotte)	....	....	....	....	....	....	....	....	....	8	51	59	8	67	75
North Kalgurli (1912) Ltd.	187	246	433	208	243	451	212	249	461	214	254	468	203	260	463
Paris Gold Mines Pty Ltd.	20	17	37	28	21	49	22	16	38	....	....	....	....	....	....
Gold Mines of Kalgoorlie (Aust.) Ltd. (Barbara and Bayleys Leases)	18	36	54	15	28	43	9	13	22	....	....	....	....	....	....
New Coolgardie Gold Mines N.L.' Callion Leases)	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Radio Gold Mines	6	5	11	5	5	10	6	5	11	7	5	12	4	4	8
†South Kalgurli Consolidated	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Sons of Gwalia Ltd.	103	143	246	96	137	233	98	119	217	9	....	9	3	....	3
Sunshine Reward Amalgamated Leases	2	2	4	2	2	4	2	2	4	2	2	4	1	1	2
All other Operators	509	283	792	524	321	845	520	341	861	513	292	835	482	256	738
State Average (inc. Diggers)	2,404	2,541	4,945	2,411	2,552	4,963	2,374	2,527	4,901	2,140	2,243	4,383	2,003	2,091	4,094

* Including Copperhead, Frasers, Nevoria, Corinthian and Pilot Groups.
ective 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.

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