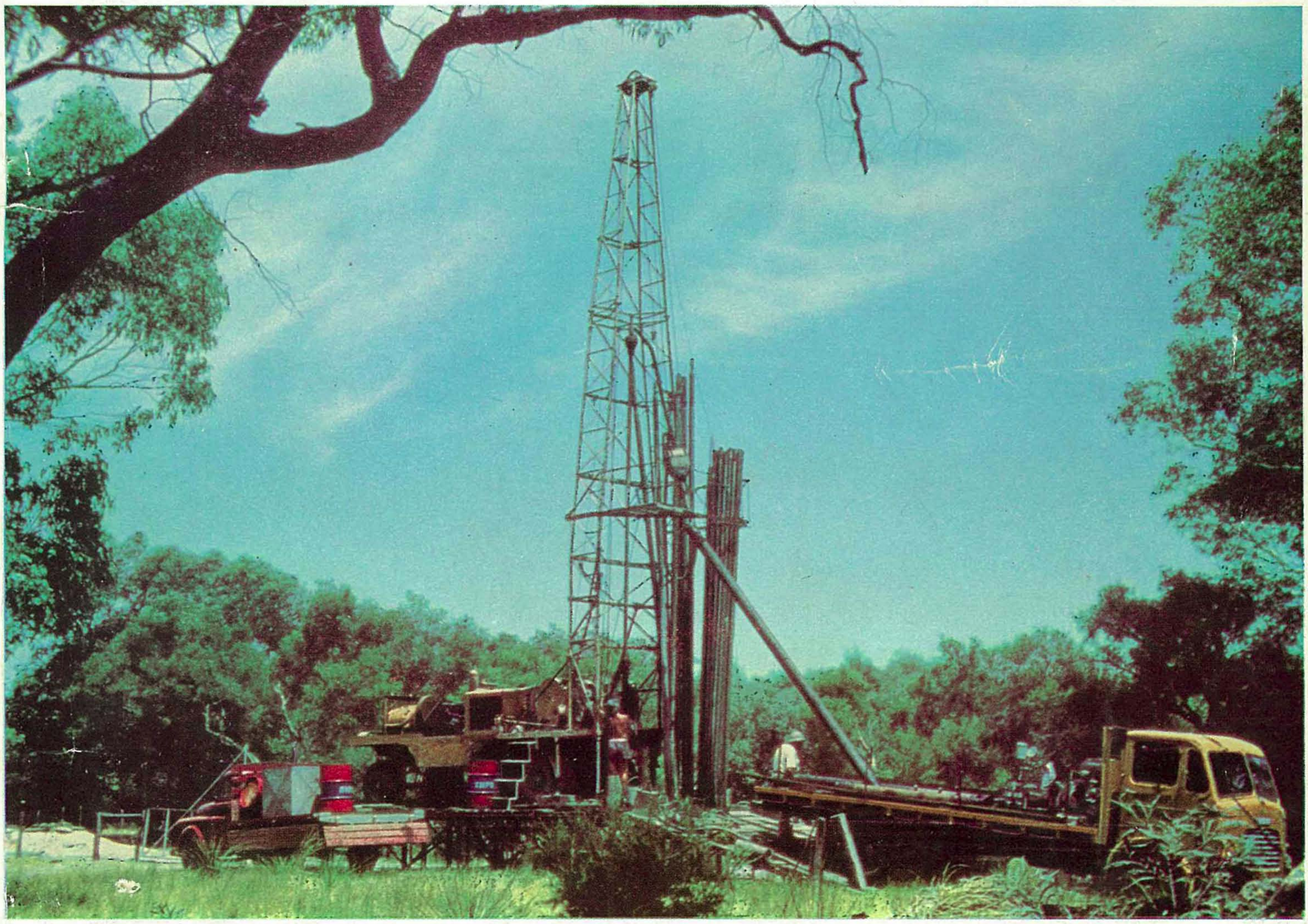
1963

Department of

REPORT OF THE MINES

WESTERN AUSTRALIA



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

REPORT OF THE DEPARTMENT *of* MINES WESTERN AUSTRALIA FOR THE YEAR 1963

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1964

83541/5/64—570

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 1963, together with reports from the officers controlling Sub-Departments, and Comparative Tables furnishing statistics relative to the Mining Industry.

I have the honour to be, Sir,

Your obedient Servant,

A. H. TELFER,

Under Secretary for Mines.

Perth, 1964.

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STATE OF WESTERN AUSTRALIA

Report of the Department of Mines for the Year 1963

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 1963.

The estimated value of the mineral output of the State for the year was £A21,076,550, a decrease of £A2,020,250 in value compared with that for the preceeding year, thus marking a halt to the series of records established over the last six successive years for all minerals.

The estimated value of gold received at the Perth Branch of the Royal Mint and exported in gold-bearing material was £A12,517,686, a decrease of £A918,044 when compared with last year, and equalled 59.39 per cent. of all minerals for 1963.

Other minerals realised: Coal, £1,985,060; iron ore (for export), £1,266,967; asbestos, £1,202,785; iron ore (for pig) £1,036,074; ilmenite, £682,067; manganese, £512,995; tin concentrates, £408,023; pyrites (for sulphur), £384,875; copper ore and concentrates, £290,120; cupreous ore and concentrates (fertiliser), £136,200; silver, £116,500; clays, £112,009; gypsum, £82,467; talc, £71,213; zircon, £45,802; magnesite, £44,167; monazite, £43,339; limestone, £33,618; tanto/columbite ores and concentrates, £23,234; rutile, £18,034; copper (metallic by-product), £13,918; beryl, £11,102; glass sand, £7,555; felspar, £6,985; lead ores and concentrates, £6,535; leucoxene, £5,983; building stone, £5,777; lithium ores, £3,979; ochre (red), £1,278; phosphatic guano, £160 and quartz grit, £43.

(See tables 1 and 1 (a), Part 11).

Tonnages of coal production from Collie were slightly less than for the previous year although the value was a little higher, whilst the number of effective workers and the proportion of deep mined coal were comparable.

Figures for the last three years being:—

	1961	1962	1963
Tons	765,740	919,112	902,495
Total Value	£1,680,259	£1,980,778	£1,985,060
Average Value per ton	43·886 sh.	43·102 sh.	43·990 sh.
Average effective workers	582	757	757
Proportion of deep mined coal	66·12%	65·12%	66·70%

Due mainly to greater world competition in the marketing of asbestos, manganese and mineral beach sands, the sequence of seven annual records established by Minerals other than Gold and Coal was temporarily halted, and returned a lower value of £6,573,804, bringing the annual aggregate for all minerals to £21,076,550.

Dividends paid by gold mining companies amounted to £2,164,495, an increase of £78,693 when compared with the previous year. (See Table 5, Part 11).

To the end of 1963, the progressive total distributed by gold mining companies amounted to £70,951,408.

To the same date the progressive value of the whole mineral production of the State amounted to £601,645,002, of which gold accounted for £483,332,430. (See Table VI at back).

GOLD

The quantity of gold advised as being received at the Perth Branch of the Royal Mint (795,546.34 fine ounces) together with that contained in gold-bearing material exported for treatment (4,665.37 fine ounces), totalled 800,211.71 fine ounces, which was 59,156.49 fine ounces less than the previous year. (See Table 1 (A) of Part 11).

The total gold yield reported directly to the Department by the producers was 802,859.78 fine ounces, a decrease of 57,179.64 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 the 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 1963, viz. 2,770,166 tons, was 219,487 tons less than the previous year, and constituted 65.54% of the State record tonnage established in 1940.

The following tonnage increases were reported from the respective Goldfields—Kimberley 120 tons, Gascoyne 19, Mt. Margaret 37,163, North Coolgardie 2,608, Broad Arrow 5,207, East Coolgardie 12,650, and Dundas 6,123; those fields showing a reduction in tonnage being Pilbara 2,635, Peak Hill 1,615, East Murchison 3,431, Yalgoo 425, North-East Coolgardie 31, Coolgardie 6,995, Yilgarn 268,131, and South West Mineral Field 58 tons.

A rise of 12,650 tons in the East Coolgardie Goldfield brought the total quantity of ore treated there during the year to 2,040,505 tons, such figure being the second highest for the field and coming within 28,659 tons of the record established in 1960.

The famous "Golden Mile" locality of Kalgoorlie-Boulder mining centres, contained in this Goldfield has to date treated 82.54 million tons of ore for 35.11 million fine ounces of gold, (equivalent to 1,074.87 tons of the precious metal itself), valued at an estimated £A266.55 million. These figures represent 55.66 per cent. of the State's reported ore tonnage and 56.06 per cent. of its gold.

During the year the four large companies now in operation there continued treating ore of regular grade with a slightly higher tonnage reported by Gold Mines of Kalgoorlie (Aust.) Ltd. This company began carting ore from their newly equipped Mt. Charlotte Leases during the latter part of the year, and from the beginning of December included approximately 1,200 tons per week therefrom for treatment at their recently expanded home plant.

The 6,123 tons increase from the Dundas Goldfield was virtually accounted for by the higher tonnage reported by the Central Norseman Gold Corporation N.L. whose average grade shaded slightly from the previous 11.226 dwts. to 10.854 dwts. per ton.

In the Mt. Margaret Goldfield where a higher output of 37,163 tons of lower grade ore had been recorded, the Sons of Gwalia Ltd. reported its highest annual treatment figure of 159,651 tons from the mine. The closure of this mine at the end of the year after a most colourful history is regrettable. The Sons of Gwalia was one of the oldest operating mining companies in the State, having been worked continuously since 1897, for the first three years of which it operated on an ore grade of over an ounce per ton, which subsequently dwindled to 3.93 dwts. per ton at its close. During its period of operations the Company had treated 7,030,740 tons for the recovery of 2,580,411 fine ounces of gold.

Cessation of operations by the Great Western Consolidated N.L. during the year was responsible for the 268,131 ton ore decline in the Yilgarn Goldfield, whilst the withdrawal of Gold Mines of Kalgoorlie (Aust.) Ltd. from the Bayley's South mine in the Coolgardie Goldfield similarly accounted for the 6,995 ton lower yield from that field.

Despite lower outputs of 4,140 tons from the Hill 50 G. M. N.L. and 1,637 tons from the Eclipse Gold Mine N.L. together with the virtual closure of the latter towards the end of the year, the Murchison Goldfield only showed a loss of 3,431 tons when compared with its previous year's effort, owing to increased activity in other localities.

The unfortunate closure of the companies mentioned coupled with restricted operations by others, should naturally affect the standard of future production unless offset by considerable existing company expansion or new resources disclosed or discovered.

Gold was priced at £15 9s. 10d. per fine ounce as from 19th September, 1949 when Sterling was devalued, and except when lifted to £15 12s. 6d. on 1st May, 1954, has remained unchanged since that date, forcing the industry to absorb the subsequent rises in costs by any conceivable means, and limiting the grade range and scale of acceptable operative possibilities in many outback areas.

West Australian gold included in sales on open dollar markets by the Gold Producers' Association Ltd., for the period from August, 1962, to August, 1963, totalled 701,242.37 fine ounces; the extra premium received therefrom in excess of Mint Value amounted to £A14,379, an overall average of 4.921 pence per fine ounce. This amount, less expenses, was distributed to the producer members during the year and approximated 4.226 per fine ounce.

Subsidy payments made by the Commonwealth Government during the year under the Gold Mining Subsidy Act, 1954-1962, totalled £670,211, an increase of £48,643 on the previous year. Of the amount distributed, £641,929 went to Large Producers, and £28,282 to Small Producers in this State.

COMPARATIVE MINERAL STATISTICS

——	1962	1963	Variation
GOLD—			
Reported to Department (Mine Production)—			
Ore (tons)	2,989,653	2,770,166	— 219,487
Gold (fine ounces)	860,039	802,860	— 57,179
Average Grade (dwts. per ton)	5·753	5·796	+ 0·043
Persons Engaged—			
(a) Effective Workers (excluding absentees)	4,963	4,901	— 62
(b) Total Pay Roll	5,353	5,297	— 56
Dividends (£A)	2,085,802	2,164,495	+ 78,693
Mint and Export (Realised Production)—			
Gold (fine ounces)	859,368	800,212	— 59,156
Estimated Value (£A) (including Overseas Gold Sales Premium)	13,435,730	12,517,686	— 918,044
COAL—			
Reported to Department (Mine Production)—			
Tons	919,112	902,495	— 16,617
Value (£A)	1,980,778	1,985,060	+ 4,282
Persons Engaged—			
Effective Workers (excluding absentees)	757	757	....
OTHER MINERALS—			
(*Reported to Department*)—			
Value (£A)	7,680,292	6,573,804	—1,106,488
Persons Engaged—			
Effective Workers (excluding absentees)	1,501	1,534	+ 33
TOTAL ALL MINERALS—			
Value (£A)	23,096,800	21,076,550	—2,020,250
Persons Engaged—			
* Effective Workers	7,221	7,192	29

* Excluding Oil Search Men which engaged an average of 154 men in the field in 1962 and 239 men in the field in 1963.

PART II—MINERALS.

During the year Royalty totalling £115,649 as against £126,248 for the preceding year, was collected under legislation passed in 1958, on certain prescribed minerals obtained from land held under the Mining Act.

Gold was exempted from royalty liability, and payment on Copper, Lead and Mineral Beach Sands, temporarily suspended on account of the depressed state of the market.

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	852	5	3
Bauxite		6	693	6	9
Bentonite		6	14	4	10
Beryl	2	0	9	12	0
Building Stone	1	0	8	5	0
Clays		6	1,320	12	1
Coal		3	10,603	14	9
Diatomacious Earth	1	6	1	2	6
Felspar		6	26	19	6
Glass Sand and Quartz Grit		6	261	4	9
Gypsum		6	1,241	6	3
Iron Ore (Export only)	1	6	92,875	9	6
Limestone		6	603	5	0
Magnesite	1	6	470	19	4
Manganese	1	6	3,744	13	6
Ochre		6	5	6	6
Petalite	1	0	19	10	0
Phosphatic Guano	1	0	3	0	0
Pyrites	1	0	2,732	5	0
Scheelite	*		10	0	0
Spodumene	1	0	3	15	0
Tanto/Columbite	*		95	2	4
Tin	2	0	53	4	0
Total			£115,649	3	10

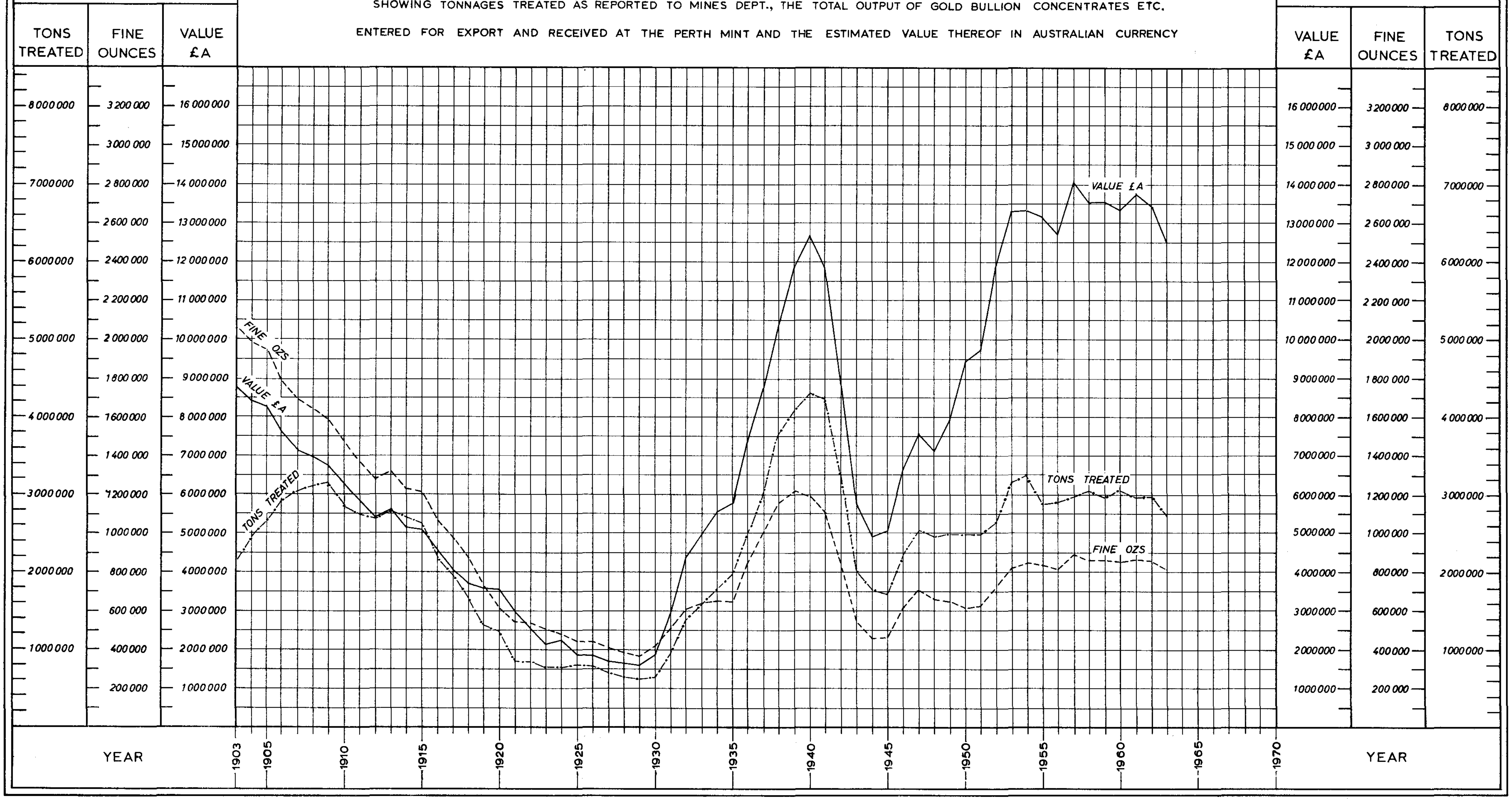
* One-half per centum of realised F.O.B. Value.

The septematic investigations of the iron ore resources of Western Australia have been vigorously maintained in 1963, and have confirmed that this State can be ranked among the largest iron ore regions in the world.

Deposits in the Pilbara area eclipse in magnitude all others in the State and Commonwealth, and there is a great deal more work to be done before a complete estimate of the potential of the region can be reliably assessed.

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



From data now available as a result of investigations by the companies holding exploration rights and by the Department's own Geological Survey Branch, the total known iron ore reserves of the State exceed 15,000 million tons of high grade iron ores.

Mining Bauxite from the Darling Range at Jarrahdale has commenced and the Alumina Refinery at Kwinana commenced treating the bauxite this year, three years ahead of schedule. In 1963 the company railed 57,206 tons of bauxite from Jarrahdale to the Kwinana refinery. When the refinery is in full production 600,000 tons of bauxite will be mined per annum.

At Greenbushes the examination of the tin field by Aberfoyle Tin N.L. has been completed. The Company is satisfied with the results and is proceeding with the project. A large dredge has been purchased in Victoria and is being dismantled for transfer to Greenbushes.

Blue asbestos and manganese production was affected by the competitive world market and showed a decline in 1963. Every effort is being made to meet market requirements and increase the production of these minerals to a grade and price attractive to buyers.

Although there was a small decline in the production of mineral beach sands during the year, the industry has established itself so that with overseas orders and the opening of the La Porte works at Bunbury for the production of titanium while it has an assured future.

Interest in minerals generally continued throughout 1963, and several large mining companies are actively exploring the State's mineral resources. Apart from those engaged in the search for iron ore Pickands Mather & Co., of America, Westfield Minerals (W.A.) Ltd. and New Consolidated Gold Fields (A'sia) Pty. Ltd. are investigating large areas for all minerals other than gold, iron and oil by the most modern scientific methods.

COAL

During the year ended 31st December, 1963, the coal production amounted to 902,495, a decrease of 16,617 when compared with last year's figures.

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

OIL

The search for oil has been stepped up with the introduction of some new companies into this field. Operations include geophysical, geological and magnetometer surveys followed where indicated by drilling.

WATER

The Hydrological Section continued to carry out geological examinations and drilling operations in connection with the Department's survey of the State's water resources. Assistance was given also to other Government Departments, local authorities and private persons to establish water supplies for specific requirements.

TABLE 1

Quantity and Value of Minerals, other than Gold and Silver, produced during Years 1962 *and* 1963
Western Australia

Description of Minerals	1962		1963		Increase or Decrease for Year compared with 1962	
	Quantity	Value	Quantity	Value	Quantity	Value
	Tons	£A	Tons	£A	Tons	£A
Asbestos (Chrysotile)	52·50	1,103	10·13	783	— 42·37	— 320
(Crocidolite)	15,616·95	1,691,933	11,094·57	1,202,002	— 4,522·38	— 489,931
Barytes	494·35	3,116	....	....	— 494·35	— 3,116
Beryl	195·46	32,452	82·03	11,102	— 113·43	— 21,350
	Lb.		Lb.		Lb.	
Bismuth	181·00	40	....	....	— 181·00	— 40
	Tons		Tons		Tons	
Building Stone* (Granite—Facing Stone)	....	....	82·00	2,160	+ 82·00	+ 2,160
(Sandstone—Donnybrook)	....	....	83·00	1,743	+ 83·00	+ 1,743
(Spongolite)	669·00	2,994	394·00	1,874	— 275·00	— 1,120
Clays (Bentonite)	485·00	1,213	1,197·00	3,875	+ 712·00	+ 2,662
(Cement Clay)	21,634·73	21,149	18,772·00	15,109	— 2,862·73	— 6,040
(Fireclay)	24,784·50	28,808	25,001·50	26,088	+ 217·00	— 2,720
(Fuller's Earth)....	120·00	480	....	....	— 120·00	— 480
(Kaolin)	....	....	125·24	285	+ 125·24	+ 285
(White Clay-Ball Clay)	682·00	4,030	794·00	3,101	+ 112·00	— 929
(Brick, Pipe and Tile Clay)*	7,112·00	8,080	56,607·00	63,551	+ 49,495·00	+ 55,471
Coal	919,112·00	1,980,778	902,494·90	1,985,060	— 16,617·10	+ 4,282
Copper (Metallic By-Product)‡	47·20	8,680	76·98	13,918	+ 29·78	+ 5,238
Copper Ore and Concentrates	5,063·22	196,718	5,860·02	290,120	+ 796·80	+ 93,402
Cupreous Ore and Concentrates (Fertiliser)	9,275·18	94,569	3,234·75	136,200	— 6,040·43	+ 41,631
Diatomaceous Earth	15·00	300	....	....	— 15·00	— 300
Felspar	1,267·00	6,884	992·00	6,985	— 275·00	+ 101
Glass Sand	10,325·62	7,708	9,926·09	7,555	— 339·53	— 153
Gypsum	51,650·13	87,879	50,808·28	82,467	— 841·85	— 5,412
Iron Ore (For Pig)	72,168·00	1,016,290	73,384·00	1,036,074	+ 1,216·00	+ 19,784
(For Export)	1,320,355·00	1,309,643	1,277,613·00	1,266,967	— 42,742·00	— 42,676
Lead Ores and Concentrates	443·03	15,156	184·93	6,535	— 258·10	— 8,621
Limestone*	36,481·25	24,008	27,895·63	33,618	— 8,585·62	+ 9,610
Lithium Ores (Petalite)	84·00	403	390·02	3,709	+ 306·02	+ 3,306
(Spodumene)	24·15	347	22·00	270	— 2·15	— 77
Magnesite	224·01	1,593	6,494·53	44,167	+ 6,270·52	+ 42,574
Manganese (Metallurgical, Battery and Low Grades)	89,602·58	1,155,862	39,356·96	512,995	— 50,245·62	— 642,867
Mineral Beach Sands (Ilmenite)	205,804·96	911,606	136,879·93	682,067	— 68,925·03	— 229,539
(Monazite)	950·15	28,544	1,048·81	43,339	+ 98·66	+ 14,795
(Rutile)	874·27	19,906	606·00	18,034	— 268·27	— 1,872
(Leucoxene)	788·55	10,767	460·00	5,983	— 328·55	— 4,784
(Zircon)	4,132·47	44,343	4,572·85	45,802	+ 440·38	+ 1,459
Ochre (Red)	....	....	212·80	1,278	+ 212·80	+ 1,278
Phosphatic Guano	68·00	680	16·00	160	— 52·00	— 520
Pyrites Ore and Concentrates (For Sulphur)	49,461·07	356,290	58,472·31	384,875	+ 9,011·24	+ 28,585
Quartz Grit	25·00	21	56·00	43	+ 31·00	+ 22
	Lb.		Lb.		Lb.	
Semi-precious Stones (Chalcedony)	448·00	200	....	....	— 448·00	— 200
	Tons		Tons		Tons	
Talc	4,980·95	71,810	4,669·15	71,213	— 311·80	— 597
Tanto/Columbite Ores and Concentrate	19·24	58,874	13·79	23,234	— 5·45	— 35,640
Tin	365·44	334,269	576·23	408,023	+ 210·79	+ 73,754
Tungsten Ores and Concentrate—Scheelite	7·35	3,883	....	....	— 7·35	— 3,883
Total	....	9,543,409	....	8,442,364	....	— 1,101,045

TABLE 1 (A)

Quantity and Value of Gold and Silver Exported and Minted during Years 1962 *and* 1963

Description of Minerals	1962		1963		Increase or Decrease for Year compared with 1962	
	Quantity	Value	Quantity	Value	Quantity	Value
	Fine oz.	£A	Fine oz.	£A	Fine oz.	£A
Gold (Exported and Minted)....	859,368·20	†13,435,730	800,211·71	†12,517,686	— 59,156·49	— 918,044
Silver (Exported and Minted)	248,460·93	117,661	203,093·18	116,500	— 45,367·75	— 1,161
Total	....	13,553,391	....	12,634,186	....	— 919,205
Grand Total	....	23,096,800	....	21,076,550	....	— 2,020,250

* Incomplete—figures relate only to production reported to the Department from holdings under the Mining Act.
† Including Overseas Gold Sales Premium.
‡ Product of Gold Mining.

TABLE 2

Value of Total Exports and Mineral Exports from Western Australia, as compared with Total Value of Mineral Production as from 1900

Year	Total Exports †	Mineral Exports (exclusive of (Coal)	Total Mineral Production
	£	£	£
1900	6,852,054	5,588,299	6,179,535
1901	8,515,623	6,789,133	7,439,470
1902	9,051,358	7,530,319	8,094,616
1903	10,234,732	8,727,060	8,971,937
1904	10,271,489	8,625,676	8,686,757
1905	9,871,019	7,731,954	8,555,841
1906	9,832,679	7,570,305	7,905,506
1907	9,904,860	7,544,992	7,669,468
1908	9,518,020	7,151,317	7,245,002
1909	8,860,494	5,906,673	7,056,079
1910	8,299,781	4,795,654	6,522,263
1911	10,606,863	7,171,638	6,105,853
1912	8,941,008	5,462,499	5,768,567
1913	9,128,607	4,608,188	6,036,115
1914	8,406,182	3,970,182	5,534,273
1915	6,291,934	2,969,502	5,478,149
1916	10,878,153	6,842,621	4,893,417
1917	9,323,229	5,022,694	4,629,028
1918	6,931,834	2,102,923	4,265,577
1919	14,279,240	6,236,585	4,061,600
1920	15,149,323	3,096,849	4,233,915
1921	10,331,405	1,373,810	3,470,597
1922	11,848,025	2,875,402	3,041,113
1923	11,999,500	3,259,476	2,747,108
1924	13,808,910	1,424,319	2,776,791
1925	13,642,852	173,126	2,393,890
1926	14,668,184	1,597,698	2,371,863
1927	15,805,120	472,041	2,202,438
1928	16,911,932	996,099	2,128,179
1929	16,660,742	1,802,709	2,087,893
1930	19,016,639	6,370,396	2,287,376
1931	14,266,650	4,333,421	3,353,923
1932	16,771,465	5,657,870	4,721,620
1933	18,098,214	5,328,869	5,239,498
1934	16,784,705	5,759,324	5,908,881
1935	17,611,547	5,698,721	6,132,811
1936	19,564,716	7,130,381	7,818,684
1937	21,594,942	9,026,313	9,210,079
1938	24,220,864	10,417,458	10,906,527
1939	23,244,509	11,969,562	12,331,659
1940	25,800,562	12,480,721	13,228,660
1941	24,536,777	12,411,316	12,398,141
1942	20,681,284	8,476,622	9,509,646
1943	18,014,340	6,539,295	6,401,594
1944	19,453,001	(*a*) 1,282,867	5,737,096
1945	20,170,624	205,587	5,910,518
1946	26,342,125	211,890	7,693,951
1947	42,389,125	4,162,892	8,862,292
1948	57,779,996	342,646	8,584,843
1949	58,197,775	465,124	9,629,300
1950	78,804,864	531,245	11,489,897
1951	115,880,457	7,479,601	12,706,228
1952	101,620,138	7,952,834	17,126,506
1953	106,678,014	13,239,076	19,358,268
1954	79,955,207	5,342,462	19,953,665
1955	113,044,633	17,145,741	18,893,161
1956	142,852,512	9,531,471	19,447,510
1957	148,128,361	12,483,343	21,007,393
1958	123,624,508	5,464,465	20,570,701
1959	137,067,544	4,536,105	21,796,605
1960	190,494,475	43,302,398	21,826,524
1961	197,204,812	21,070,266	22,376,840
1962	176,424,488	10,893,040	23,096,800
1963	189,687,098	11,540,795	21,076,550

† Including Ships' Stores.

(*a*) Full value and use of gold, not always exported, as utilised by the Commonwealth Treasury in the financing of Australian Trade Economy from 1944, not available

TABLE 3

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	
	1962	**1963**	1962	**1963**	1962*	**1963***
	Fine oz.	Fine oz.	Per cent.	Per cent.	Dwts.	Dwts.
1. Kimberley	31	**160**	·004	**·020**	....	**26·667**
2. West Kimberley	....	....	....	....	....	....
3. Pilbara	1,603	**1,764**	·186	**·220**	7·340	**18·251**
4. West Pilbara	9	....	·001	....	1·682	....
5. Ashburton	....	....	....	....	....	....
6. Gascoyne	274	**241**	·032	**·030**	52·190	**38·871**
7. Peak Hill	269	**87**	·031	**·011**	2·212	**2·130**
8. East Murchison	353	**278**	·041	**·035**	10·014	**10·549**
9. Murchison	94,679	**83,701**	11·009	**10·425**	10·851	**9·785**
10. Yalgoo	153	**101**	·018	**·013**	5·222	**12·547**
11. Mt. Margaret	27,186	**31,982**	3·161	**3·983**	4·337	**3·911**
12. North Coolgardie	17,567	**18,356**	2·042	**2·286**	10·871	**10·511**
13. Broad Arrow	935	**1,285**	·109	**·160**	5·826	**3·053**
14. North-East Coolgardie	138	**232**	·016	**·029**	4·313	**7·607**
15. East Coolgardie	526,478	**531,102**	61·216	**66·151**	5·192	**5·206**
16. Coolgardie	11,888	**10,139**	1·382	**1·263**	6·476	**6·824**
17. Yilgarn	65,138	**17,904**	7·574	**2·230**	3·282	**2·780**
18. Dundas	110,252	**102,951**	12–819	**12·823**	12·002	**10·846**
19. Phillips River	†2,987	**†2,542**	·347	**·317**	....	....
20. South-West Mineral Field	41	**33**	·005	**·004**	10·933	**38·824**
21. State Generally	58	**2**	·007	....	....	....
	860,039	**802,860**	100·000	**100·000**	5·753	**5·796**

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

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

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

† By-product of Copper Mining.

TABLE 4

Output of Gold from the Commonwealth of Australia during 1963

State	Output of Gold	Value*†	Percentage of Total
	Fine oz.	£A	%
Western Australia	800,212	12,503,312	78·756
Victoria	24,744	386,625	2·435
New South Wales	11,602	181,281	1·142
Queensland	67,762	1,058,781	6·669
Tasmania	31,989	499,828	3·148
South Australia	16	250	·002
Northern Territory	79,737	1,245,891	7·848
Total	1,016,062	15,875,968	100·000

* £A15 12s. 6d. per fine ounce.

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

TABLE 5

Dividends, etc., paid by Western Australian Gold Mining Companies during 1963, *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	
		1963	Grand Total to end of 1963
		£	£
Pilbara	Various Companies	....	26,513
Peak Hill	do. do.	....	199,305
East Murchison	do. do.	....	1,914,053
Murchison	Eclipse Gold Mine N.L.	....	67,200
	Hill 50 Gold Mine N.L.	450,000	7,365,626
	Various Companies	....	2,764,945
Mt. Margaret	Sons of Gwalia Ltd.	....	2,075,050
	Various Companies	....	958,286
North Coolgardie	Moonlight Wiluna G.M.s Ltd.	112,500	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.	271,057	3,077,203
	Great Boulder G.M.s Ltd.	218,750	9,590,650
	Lake View & Star Ltd.	437,500	(*b*) 10,680,750
	North Kalgurli (1912) Ltd.	154,688	3,258,749
	Various Companies	....	(*a*) 19,496,816
Coolgardie	do. do.	....	410,000
Yilgarn	do. do.	....	(*c*) 1,205,556
Dundas	Central Norseman Gold Corporation N.L.	520,000	6,012,500
	Various Companies	....	786,162
	Totals	2,164,495	70,951,408

(*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 6

Total Coal output from Collie River Mineral Field, 1962 *and* 1963, *estimated Value thereof, Number of Men employed, and output per Man as reported Monthly*

Year	Total Output	Estimated Value	Men Employed			Output per Man Employed		
			Above Ground	Under Ground	Above and Under Ground	Above Ground	Under Ground	Above and Under Ground
Deep Mining—	Tons	£A	No.	No.	No.	Tons	Tons	Tons
1962	598,501	1,539,941	130	500	630	*4,604	*1,197	950
1963	600,934	1,570,551	136	517	653	4,418	1,162	920
Open Cut Mining—								
1962	320,611	440,837	127	....	127	2,524	....	2,524
1963	301,561	414,509	104	....	104	2,899	....	2,899
Totals—								
1962	919,112	1,980,778	257	500	757	3,576	1,838	1,214
1963	902,495	1,985,060	240	517	757	3,760	1,742	1,192

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

TABLE 7

MINING ACT

Total Number and Acreage of Mining Tenements applied for during 1962 *and in force as at* 31*st December*, 1963 (*Compared with* 1962)

——	Applied for				In Force			
	1962		1963		1962		1963	
	No.	Acreage	No.	Acreage	No.	Acreage	No.	Acreage
Gold—								
Gold Mining Leases	80	1,468	84	1,488	983	18,025	989	18,253
Dredging Claims	....	....	1	300	1	12	2	312
Prospecting Areas	568	9,836	398	6,915	454	7,711	373	6,381
Temporary Reserves	57	15,373	12	3,005	83	21,663	80	23,155
Total	705	26,677	411	11,708	1,521	47,411	1,444	48,101
Coal—								
Coal Mining Leases	8	2,240	25	7,418	72	21,329	72	21,229
Prospecting Areas	1	1,550	....	....	....	....	....	....
Temporary Reserves	....	....	....	....	2	4,800,000	1	1,600,000
Total	9	3,790	25	7,418	74	4,821,329	73	1,621,229
Other Minerals—								
Mineral Leases	21	637	62	1,300	107	2,690	133	3,773
Dredging Claims	87	15,877	56	9,869	148	7,916	148	10,905
Mineral Claims	135	21,892	251	38,419	769	71,081	929	98,155
Prospecting Areas	91	1,969	76	1,570	66	1,420	70	3,764
Temporary Reserves	90	15,500,160	74	33,372,160	208	117,246,453	177	151,360,160
Total	424	15,540,535	519	33,423,318	1,298	117,329,560	1,457	151,476,757
Other Holdings—								
Miner's Homestead Leases	8	288	5	85	361	31,527	309	33,530
Miscellaneous Leases	5	42	15	133	109	1,782	110	1,674
Residence Areas	....	....	2	1	69	23	73	28
Business Areas	1	1	2	2	24	19	27	23
Machinery Areas	7	24	1	3	30	86	29	83
Tailings Areas	3	7	2	8	21	82	23	90
Garden Areas	1	5	4	9	80	246	81	253
Quarrying Areas	....	....	2	39	8	74	7	73
Water Rights	12	83	5	38	134	2,460	118	2,442
Licenses to Treat Tailings	32	....	39	....	37	....	46	....
Total	69	450	77	318	873	36,299	823	38,196
Grand Totals	1,207	15,571,452	1,032	33,442,762	3,766	122,234,599	3,797	153,184,283

TABLE 7(a)

SPECIAL ACTS

Total Number and Acreage of Mining Leases applied for during 1963 *and in force at* 31*st December*, 1963 (*Compared with* 1962)

Holding	Applied for				In Force			
	1962		1963		1962		1963	
	No.	Acreage	No.	Acreage	No.	Acreage	No.	Acreage
Mineral Leases	....	....	....	....	2	1,817,111	2	1,817,111

TABLE 7 (b)

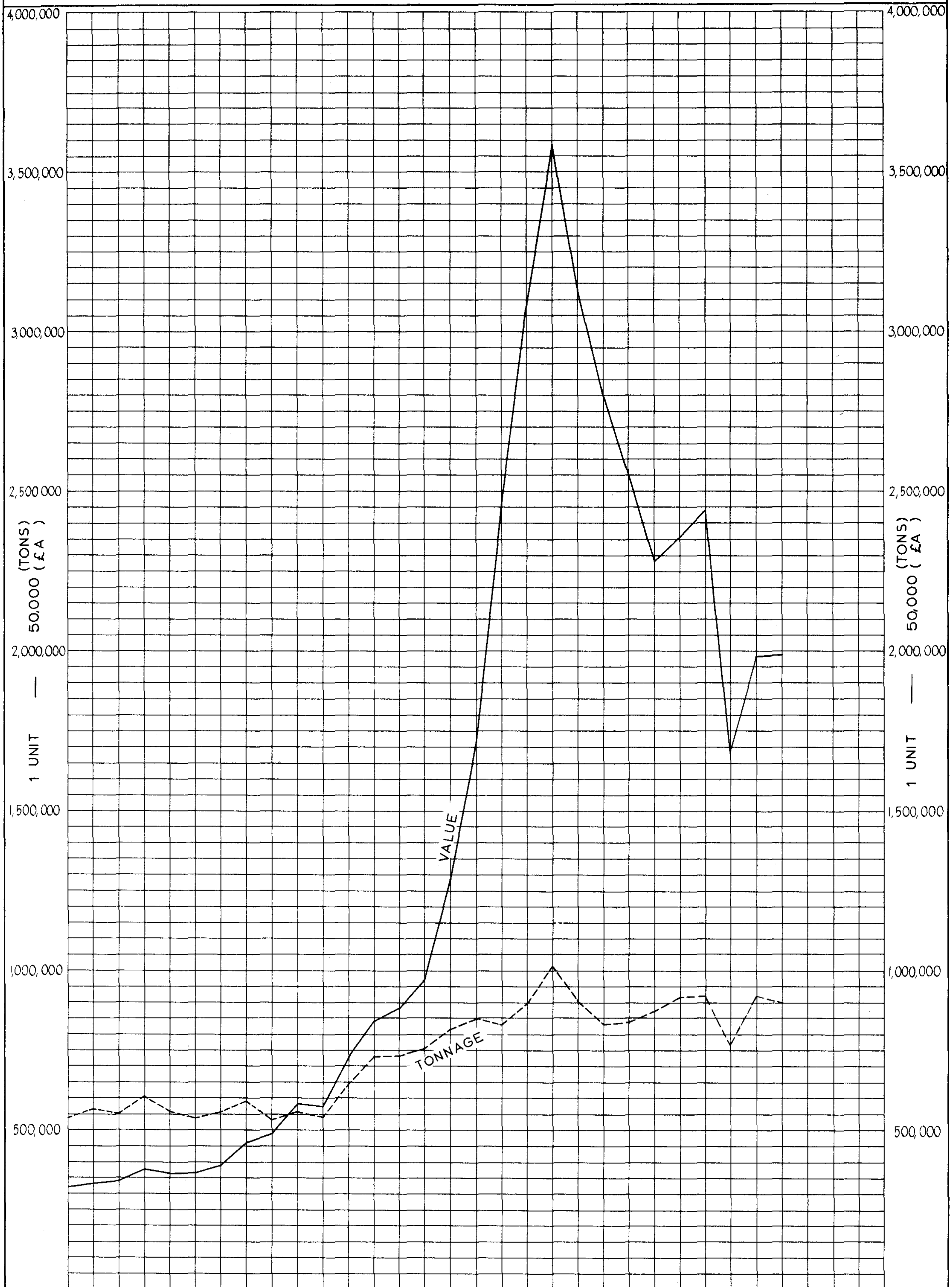
PETROLEUM ACT

Total Number and Acreage of Permits to Explore and Licenses to Prospect applied for during 1963 *and in force at* 31*st December*, 1963 (*Compared with* 1962)

Holding	Applied for				In Force			
	1962		1963		1962		1963	
	No.	Acreage	No.	Acreage	No.	Acreage	No.	Acreage
Permits to Explore	46	362,080,000	10	131,499,520	44	466,425,600	37	436,272,000
Licenses to Prospect	7	817,280	5	636,800	47	5,430,624	49	5,523,200
Totals	53	362,897,280	15	132,136,320	91	471,856,224	86	441,795,200

GRAPH OF COAL OUTPUT

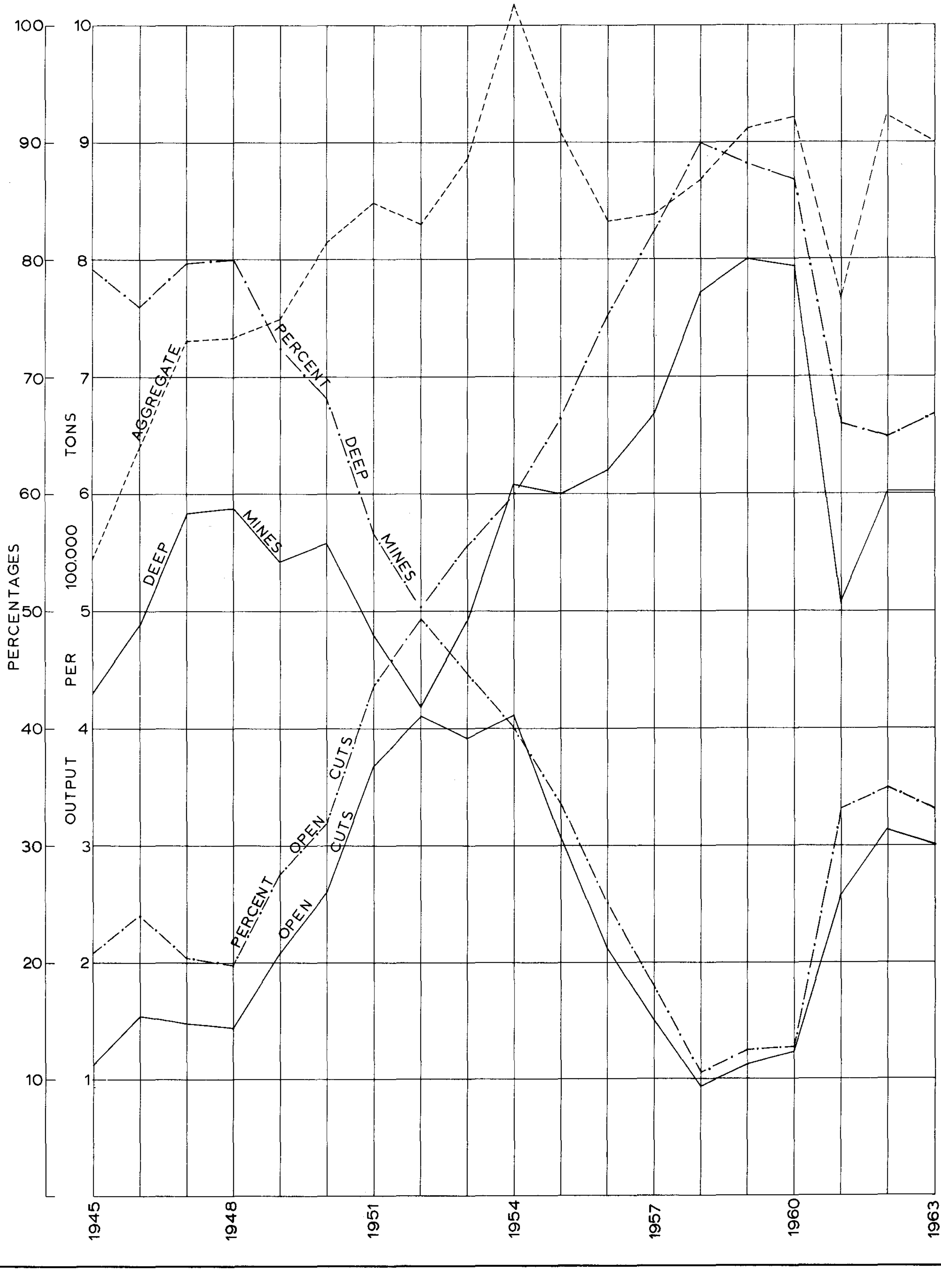
SHOWING QUANTITIES AND VALUES AS REPORTED TO MINES DEPT.



YEAR	VALUE £A	TONS
1935	318013	537188
1936	331565	565075
1937	340444	553510
1938	375083	604793
1939	362811	557535
1940	364500	539427
1941	389278	556574
1942	461495	581176
1943	489721	531546
1944	583075	558322
1945	572896	543363
1946	730104	642287
1947	840249	730506
1948	880236	732938
1949	972245	750594
1950	1,287,749	814351
1951	1,716,788	848475
1952	2,457,296	830461
1953	3,073,073	886182
1954	3,588,818	1,018,343
1955	3,132,074	903,792
1956	2,797,506	830008
1957	2,552,655	838660
1958	2,280,649	870882
1959	2,356,534	917434
1960	2,439,195	922393
1961	1,680,259	765,740
1962	1,980,778	919,112
1963	1,985,060	902,495
1964		
1965		
1966		
1967		

GRAPH OF TREND IN COAL OUTPUT

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



Total Area of Leases Applied for, Approved and in Force as at 31st December, 1963

Goldfield or Mineral Field District	Gold Mining Leases			Mineral Leases			Miner's Homestead Leases			Miscellaneous Leases		
	Applied for	Ap-proved	In Force	Applied for	Ap-proved	In Force	Applied for	Ap-proved	In Force	Applied for	Ap-proved	In Force
Ashburton	10	24	136	....	....	....	....	....	500	....	....	....
Black Range	18	42	62	....	....	....	....	....	....	....	....	....
Broad Arrow	111	99	290	....	....	....	....	....	....	....	....	5
Bulong	....	....	36	....	....	....	....	....	....	....	....	3
Collie	....	....	....	4,250	....	20,409	....	....	....	....	....	....
Private Property	....	....	....	3,168	....	820	....	....	....	....	....	....
Coolgardie	62	110	760	....	....	295	....	....	1,840	....	....	28
Cue	....	....	32	....	....	....	....	....	1,233	....	....	....
Day Dawn	96	96	462	....	....	....	....	....	20	....	....	....
Dundas	233	233	6,174	....	....	....	....	....	589	....	....	....
East Coolgardie	323	302	5,284	....	....	....	45	5	3,633	....	....	1,258
Gascoyne	48	24	48	48	48	56	....	....	....	....	....	....
Greenbushes	....	....	....	....	....	77	....	....	588	....	....	....
Kanowna	....	....	22	....	....	....	....	....	702	....	....	....
Kimberley	10	10	46	24	24	396	....	....	....	....	....	....
Kunanalling	24	24	47	48	48	48	....	....	520	....	....	....
Kurnalpi	48	48	96	....	....	....	....	....	....	....	....	....
Lawlers	76	100	440	....	....	....	....	....	1,110	....	....	43
Marble Bar	6	27	274	....	....	40	....	....	13	....	10	35
Meekatharra	24	12	144	36	36	36	....	....	2,165	....	....	1
Menzies	23	23	366	....	....	....	....	....	740	....	....	10
Mount Magnet	18	37	1,024	....	....	38	....	....	30	....	....	....
Mount Malcolm	....	....	653	....	....	....	....	....	1,270	....	....	....
Mount Margaret	24	24	42	....	....	....	....	....	58	....	....	....
Mount Morgans	....	....	57	....	....	....	....	....	....	....	....	....
Niagara	....	....	107	....	....	....	....	....	20	....	....	....
Northampton	....	....	....	24	24	103	....	....	53	....	....	....
Private Property	....	....	....	....	....	....	....	....	....	....	....	....
Nullagine	....	....	198	....	....	....	....	....	22	....	....	48
Peak Hill	24	24	75	24	....	403	....	....	300	....	....	5
Phillips River	12	12	21	....	....	246	....	....	14,244	....	....	....
Private Property	....	....	....	....	....	....	....	....	....	....	....	....
South-West M.F.	24	24	48	....	....	28	....	....	....	....	....	....
Private Property	168	....	24	1,096	1,096	1,096	....	....	....	....	....	....
Ularring	....	....	132	....	....	....	....	....	20	....	....	....
West Kimberley	....	....	....	....	....	755	....	....	....	75	75	75
West Pilbara	....	44	56	....	....	156	....	....	11	....	....	147
Wiluna	24	....	....	....	....	....	....	....	3,876	....	....	11
Yalgoo	28	28	94	....	....	....	....	....	10	....	....	....
Yerilla	24	24	376	....	....	....	....	....	10	....	....	....
Yilgarn	30	56	627	....	....	....	40	29	453	58	5	5
Private Property	....	....	....	....	....	....	....	....	....	....	....	....
Outside Proclaimed	....	....	....	....	....	....	....	....	....	....	....	....
Private Property	....	....	....	....	....	....	....	....	....	....	....	....
Totals	1,488	1,447	18,253	8,718	1,276	25,002	85	34	33,530	133	90	1,674

Total Area of Claims and Authorised Holdings Applied for, Granted and in Force as at 31st December 1963

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	....	....	....	855	176	7,492	....	....	6	38
Black Range	47	47	47	....	....	24	1	1	1	....
Broad Arrow	689	605	556	76	76	24	....	....	11	8
Bulong	157	169	169	20	20	143	....	....	....	....
Collie	....	....	....	....	....	....	....	....	....	7
Private Property	....	....	....	....	....	....	....	....	....	....
Coolgardie	1,486	1,469	1,200	4,263	93	1,345	6	3	31	153
Cue	245	233	161	46	12	114	....	....	1	72
Day Dawn	130	130	118	....	....	....	....	....	23	....
Dundas	242	210	162	1,584	48	641	....	....	19	69
East Coolgardie	710	705	677	48	48	48	6	6	170	701
Gascoyne	34	10	....	638	68	256	....	....	5	53
Greenbushes	....	....	....	3,615	2,870	5,389	31	8	51	13
Kanowna	90	100	100	....	....	....	....	....	8	....
Kimberley	....	....	....	....	....	....	....	....	3	6
Kunanalling	162	162	162	....	....	....	....	....	26	....
Kurnalpi	180	180	132	24	....	....	....	....	....	....
Lawlers	264	264	288	24	24	54	....	....	12	....
Marble Bar	156	156	156	14,913	12,901	22,569	7	27	711	120
Menzies	302	302	222	24	24	....	1	1	24	22
Mount Magnet	488	439	439	....	....	....	5	5	47	148
Mount Malcolm	403	403	343	....	....	....	....	....	203	136
Mount Margaret	106	106	82	....	....	....	....	....	4	....
Mount Morgans	70	70	70	....	....	29	....	....	1	....
Niagara	66	66	60	....	....	....	....	....	4	....
Northampton	....	....	....	230	12	524	....	....	....	9
Private Property	....	....	....	....	....	....	....	....	....	....
Nullagine	381	369	336	267	24	2,670	2	2	61	....
Peak Hill	39	39	39	10	10	1,029	....	....	11	....
Phillips River	....	....	....	557	100	3,859	....	....	5	36
Private Property	....	....	....	115	345	724	....	....	....	....
Meekatharra	150	126	182	240	216	222	....	....	10	77
South-West M.F.	12	84	84	5,144	8,168	19,353	....	....	7	667
Private Property	168	144	72	16,527	8,825	15,049	....	....	....	....
Ularring	40	40	40	....	....	....	....	....	13	9
West Kimberley	....	....	....	....	....	48	39	15	53	7
West Pilbara	....	....	....	216	694	26,053	1	1	74	....
Wiluna	6	6	6	....	....	....	....	....	1,336	....
Yalgoo	76	76	76	470	470	985	6	6	13	13
Yerilla	108	84	72	....	....	....	....	....	12	....
Yilgarn	822	688	594	....	....	3,460	1	1	36	175
Private Property	....	....	....	....	....	....	....	....	....	....
Outside Proclaimed	96	48	48	....	....	720	....	....	....	....
Private Property	....	....	....	....	....	....	....	....	....	....
Totals	7,925	7,530	6,693	49,906	35,224	112,824	106	76	2,992	2,539

Claims and Authorised Holdings in Force on the 31st December, **1963**

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	3	72	4	184	38	7,236	....	....	....	....	....	....	....	....	....	....	....	....	1	6
Black Range	3	47	....	....	1	24	4	1	....	....	....	....	....	....	....	....	....	....	....	....
Broad Arrow	34	580	....	....	....	....	1	1	1	1	....	....	....	....	....	....	4	9	....	....
Bulong	11	189	....	....	2	123	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Collie	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Private Property	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Coolgardie	67	1,224	....	....	11	1,321	3	1	....	....	1	1	1	3	4	9	5	17	....	....
Cue	13	173	....	....	8	102	3	1	....	....	....	....	....	....	....	....	....	....	....	....
Day Dawn	7	118	....	....	....	....	....	....	....	....	....	....	....	....	4	20	2	3	....	....
Dundas	9	186	....	....	25	617	....	....	....	....	....	....	1	5	1	2	2	12	....	....
East Coolgardie	51	701	....	....	1	24	31	8	....	....	3	9	12	56	4	17	13	39	4	41
Gascoyne	3	68	....	....	3	188	....	....	....	....	1	5	....	....	....	....	....	....	....	....
Greenbushes	....	....	2	524	52	4,865	1	1	....	....	....	....	....	....	10	42	1	8	....	....
Kanowna	7	100	....	....	....	....	....	....	....	....	....	....	....	....	2	7	1	1	....	....
Kimberley	....	....	....	....	....	....	....	....	....	....	....	....	....	....	1	3	....	....	....	....
Kunanalling	10	162	....	....	....	....	1	1	....	....	....	....	....	....	....	....	3	25	....	....
Kurnalpi	6	132	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Lawlers	13	300	....	....	3	42	....	....	....	....	2	6	1	5	....	....	1	1	....	....
Marble Bar	22	422	138	9,688	154	12,615	2	1	6	7	8	26	1	5	2	2	14	670	....	....
Meekatharra	12	218	....	....	2	186	....	....	....	....	....	....	....	....	1	5	2	5	....	....
Menzies	14	222	....	....	....	....	....	....	....	....	1	1	....	....	4	13	5	10	....	....
Mount Magnet	27	439	....	....	....	....	1	1	....	....	....	....	....	....	21	41	4	5	....	....
Mount Malcolm	18	343	....	....	....	....	....	....	....	....	....	....	....	....	11	38	10	165	....	....
Mount Margaret	4	82	....	....	....	....	....	....	....	....	....	....	....	....	....	....	4	4	....	....
Mount Morgans	4	70	....	....	1	29	....	....	....	....	....	....	....	....	....	....	1	1	....	....
Niagara	3	60	....	....	....	....	....	....	....	....	....	....	....	....	....	....	2	4	....	....
Northampton	1	12	....	....	6	512	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Private Property	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Nullagine	11	210	1	300	64	2,496	....	....	....	....	2	2	3	4	3	6	15	49	....	....
Peak Hill	4	49	....	....	29	1,019	1	1	....	....	1	5	1	5	....	....	....	....	....	....
Phillips River	3	72	....	....	42	3,787	1	5	....	....	....	....	....	....	....	....	....	....	....	....
Private Property	....	....	....	....	4	724	....	....	....	....	....	....	....	....	....	....	....	....	....	....
South-West M.F.	4	84	12	2,546	152	16,807	....	....	....	....	....	....	....	....	....	....	1	7	....	....
Private Property	4	96	5	521	95	14,504	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Ularring	2	40	....	....	....	....	....	....	....	....	1	1	2	4	....	....	7	8	....	....
West Kimberley	....	....	....	....	1	48	....	....	....	....	2	10	....	....	1	5	1	12	2	26
West Pilbara	6	144	....	....	158	25,909	4	1	12	12	....	....	....	....	4	19	8	42	....	....
Wiluna	1	6	....	....	....	....	....	....	....	....	2	3	1	3	1	5	5	1,325	....	....
Yalgoo	12	264	....	....	11	797	....	....	6	2	1	3	....	....	....	....	2	8	....	....
Yerilla	5	72	....	....	....	....	....	....	....	....	....	....	....	....	....	....	5	12	....	....
Yilgarn	35	594	....	....	34	3,460	20	5	2	1	4	11	....	....	7	19	....	....	....	....
Private Property	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Outside Proclaimed	2	48	....	....	3	720	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Private Property	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Totals	431	7,599	162	13,763	929	98,155	73	28	27	23	29	83	23	90	81	253	118	2,442	7	73

Alluvial Claims—None in Force. Miner's Rights issued—2,539.

Number and Area of all Leases in Force on 31st December, 1963

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	500	....	....
Broad Arrow	21	290	....	....	....	....	1	5
Black Range	5	62	....	....	....	....	....	....
Bulong	2	36	....	....	....	....	1	3
Collie .... }	....	....	69	20,409	....	....	....	....
Private Property .... }	....	....	3	820	....	....	....	....
Coolgardie	45	760	14	295	21	1,840	4	28
Cue	3	32	....	....	6	1,233	....	....
Day Dawn	22	462	....	....	1	20	....	....
Dundas	281	6,174	....	....	18	589	....	....
East Coolgardie	297	5,284	....	....	81	3,633	72	1,258
Gascoyne	2	48	2	56	....	....	....	....
Greenbushes	....	....	2	77	11	588	....	....
Kanowna	2	22	....	....	12	702	....	....
Kimberley	4	46	13	396	....	....	....	....
Kunanalling	2	47	1	48	2	520	....	....
Kurnalpi	4	96	....	....	....	....	....	....
Lawlers	23	440	....	....	5	1,110	4	43
Marble Bar	24	274	2	40	2	13	4	35
Meekatharra	9	144	3	36	11	2,165	1	1
Menzies	23	366	....	....	7	740	1	10
Mount Magnet	64	1,024	4	38	2	30	....	....
Mount Malcolm	31	653	....	....	9	1,270	....	....
Mount Margaret	2	42	....	....	7	58	....	....
Mount Morgans	3	57	....	....	....	....	....	....
Niagara	6	107	....	....	1	20	....	....
Northampton .... }	....	....	6	103	1	53	....	....
Private Property .... }	....	....	....	....	....	....	....	....
Nullagine	11	198	....	....	2	22	2	48
Peak Hill	9	75	12	403	6	300	1	5
Phillips River	2	21	11	246	108	14,244	....	....
South-West .... }	2	48	1	28	....	....	....	....
Private Property .... }	1	24	28	1.096	....	....	....	....
Ularring	10	132	....	....	1	20	....	....
West Kimberley	....	....	23	755	....	....	5	75
West Pilbara	3	56	11	156	2	11	8	147
Wiluna	....	....	....	....	17	3,876	3	11
Yalgoo	7	94	....	....	1	10	....	....
Yerilla	19	376	....	....	1	10	....	....
Yilgarn .... }	41	627	....	....	24	453	3	5
Private Property .... }	....	....	....	....	....	....	....	....
Outside Proclaimed .... }	....	....	....	....	....	....	....	....
Private Property .... }	....	....	....	....	....	....	....	....
Totals	989	18,253	205	25,002	309	33,530	110	1,674

	Acres
Gold Mining Leases on Crown Land	988–18,229
Gold Mining Leases on Private Property	1– 24
Miner's Homestead Leases on Crown Land	309–33,530
Miner's Homestead Leases on Private Property	*Nil*
Mineral Leases on Crown Land	174–23,086
Mineral Leases on Private Property	31– 1,916
Other Leases on Crown Land	110– 1,674

PART IV—MEN EMPLOYED

TABLE 8

Average number of Men reported as engaged in Mining during 1961 *and* 1962

Goldfield	District	Total 1962	Total 1963
Kimberley	....	4	....
West Kimberley	....	....	....
Pilbara	Marble Bar	20	26
	Nullagine	37	18
West Pilbara	....	3	1
Ashburton	....	....	....
Gascoyne	....	....	....
Peak Hill	....	6	....
East Murchison	Lawlers	18	19
	Wiluna	2	3
	Black Range	2	4
Murchison	Cue	25	31
	Meekatharra	22	12
	Day Dawn	7	12
	Mt. Magnet	243	250
Yalgoo	....	4	....
Mt. Margaret	Mt. Morgans	2	2
	Mt. Malcolm	242	231
	Mt. Margaret	5	2
North Coolgardie	Menzies	113	103
	Ularring	40	37
	Niagara	5	5
	Yerilla	25	23
Broad Arrow	....	89	....
North-East Coolgardie	Kanowna	30	28
	Kurnalpi	13	17
East Coolgardie	East Coolgardie	3,035	3,179
	Bulong	11	10
Coolgardie	Coolgardie	191	166
	Kunanalling	19	20
Yilgarn	....	368	231
Dundas	....	376	369
Phillips River	....	2	....
South-West Mineral Field	....	4	....
Total, Gold Mining	....	4,963	4,901
Minerals Other than Gold—			
Asbestos		416	351
Barytes		2	1
Bauxite		....	7
Bentonite		1	2
Beryl		45	35
Building Stone		1	2
Clays		10	13
Coal		757	757
Copper		133	117
Cupreous Ore (Fertiliser)		45	72
Felspar		5	5
Glass Sand		3	3
Gypsum		16	20
Iron Ore		359	417
Lead		3	2
Limestone		15	16
Magnesite		7	1
Manganese		73	28
Mineral Beach Sands (Ilmenite, etc.)		199	213
Ochre		....	....
Phosphatic Guano		....	....
Pyrites		102	99
Spodumene		....	2
Talc		5	3
Tanto/Columbite		4	8
Tin		57	117
Total, Other Minerals		2,258	2,291

PART V—ACCIDENTS

TABLE 9

Men employed in mines, killed and injured in mining accidents during 1962-63
A. According to Locality of accident.

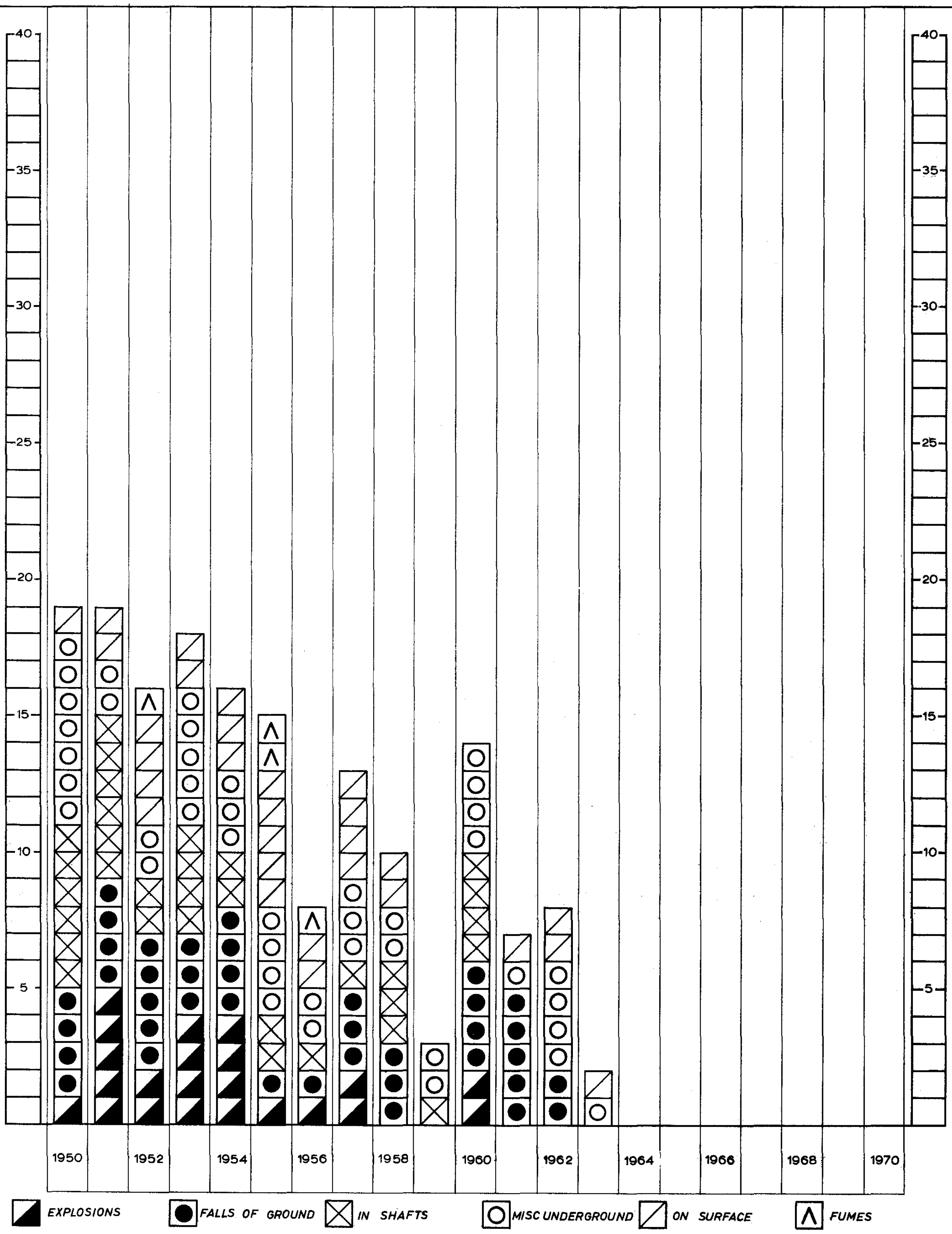
Goldfield	Killed		Injured		Total Killed and Injured	
	1962	**1963**	1962	**1963**	1962	**1963**
1. Kimberley	....	....	....	....	....	....
2. West Kimberley	....	....	10	**2**	10	**2**
3. Pilbara	2	....	1	**1**	3	**1**
4. West Pilbara	1	....	13	**12**	14	**12**
5. Ashburton	....	....	3	**4**	3	**4**
6. Gascoyne	....	....	....	**4**	....	**4**
7. Peak Hill	....	....	....	....	....	....
8. East Murchison	....	....	....	....	....	....
9. Murchison	....	....	18	**18**	18	**18**
10. Yalgoo	....	....	....	....	....	....
11. Mount Margaret	....	....	24	**27**	24	**27**
12. North Coolgardie	....	....	2	**6**	2	**6**
13. North-East Coolgardie	....	....	....	....	....	....
14. Broad Arrow	....	....	1	....	1	....
15. East Coolgardie	3	**1**	217	**245**	220	**246**
16. Coolgardie	....	....	5	**4**	5	**4**
17. Yilgarn	....	....	13	**10**	13	**10**
18. Dundas	....	....	30	**33**	30	**33**
19. Phillips River	....	**1**	19	**11**	19	**12**
Mining Districts—						
Northampton	....	....	....	....	....	....
Greenbushes	....	....	....	....	....	....
Collie	....	....	70	**56**	70	**56**
South-West	2	**1**	23	**12**	25	**13**
Total	8	**3**	449	**445**	457	**448**

B.—*According to Causes of Accidents*

	1962		1963		Comparison with 1962	
	Fatal	Serious	Fatal	Serious	Fatal	Serious
1. Explosives	....	**5**	....	**5**	....	....
2. Falls of Ground	2	**52**	....	**30**	— 2	— **22**
3. In Shafts	....	**8**	....	**8**	....	....
4. Miscellaneous Underground	4	**278**	1	**281**	— 3	+ **3**
5. Surface	2	**106**	2	**121**	....	+ **15**
6. Fumes	....	....	....	....	....	....
Total	8	**449**	3	**445**	— 5	— **4**

DIAGRAM OF ACCIDENTS

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



PART VI—STATE AID TO MINING.

(a) State Batteries.

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

From inception to the end of 1963, gold, tin, tungsten, lead, copper and tantalite ores to the value of £18,509,405 have been treated at the State Batteries. Included in the above amount is gold premium of £7,048,325 and premium paid by sales of gold by the Gold Producers Association Ltd., of £43,162. £18,076,045 came from 3,417,388 tons of gold ore, £94,793 from 81,894 tons of tin ore, £18,850 from 3,960 tons tungsten ore, £301,751 from 28,695½ tons of lead ore, £5,966 from 220½ tons of copper ore and £12,000 from 95 tons of tantalite ore.

During the year 43,944¼ tons of gold ores were crushed for 15,618 ozs. bullion, estimated to contain 13,236 ozs. fine gold, equal to 6 dwts. per ton. The average value of sands after amalgamation was 3 dwts. 5 grs. per ton, making the average head value 9 dwts. 5 grs. per ton. Cyanide plants produced 2,260 ozs. fine gold, giving a total estimated production for the year of 15,496 ozs. fine gold valued at £242,568.

The working expenditure for the year for all plants was £214,774 and the revenue was £35,710 giving a working loss of £179,064 which does not include depreciation or interest. Since the inception of State Batteries, the Capital expenditure has been £813,429 made up of £633,817 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 £22,687 compared with £21,028 for 1962.

The working expenditure from inception to the end of 1963 exceeds revenue by £1,875,182.

(b) Prospecting Scheme.

The number of men approved for assistance under the prospecting scheme during the year ended 31st December, 1963 was 54, an increase of 13 over last year's figure. There were 52 cancellations, and after allowing for 4 men under suspension there were 48 men in receipt of assistance as at 31st December, 1963.

The total cost of maintaining the scheme for the year was £11,072 5s. 3d. and refunds amounted to £1,779 2s. 8d.

Prospectors crushed 1,403 tons of ore for a return of 390 ozs. 12 dwts. of gold.

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

Expenditure	£439,870 8 10
Refunds	£87,260 1 3
Or Crushed	117,117¾ tons
R eurn	55,349 ozs. 17 dwts.

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

(c) Geological Survey of Western Australia.

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

Geological field parties working in the north-West completed mapping the geology of the Hamersley Iron Province. This province is considered to be one of the largest iron ore fields in the world. The Survey gave considerable assistance to exploration companies in this area.

Systematic regional geological mapping continued in the Kimberley, Pilbara, Ashburton and Kalgoorlie-Norseman areas of the State. Exploration companies were provided with basic geological data which helped their search for gold and other minerals.

Investigation of underground water by geological mapping, geophysical methods and exploratory drilling continued in widely separated areas, recognising water as the most important mineral to the State and providing direct aid to agriculture and the pastoral industry.

Substantial underground water supplies were located by exploratory drilling for additional town water supplies needed for Perth, Geraldton and Mandurah.

Provision of engineering geology services on the Standard Gauge Railway and a number of dam sites, assisted both the Government and private contractors to carry out preventative and remedial treatment on the projects.

Basic mapping and research work in the "Lennard Shelf" area of the Canning Basin was again undertaken to directly assist oil exploration companies in their future drilling in the area.

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

In addition to work in the field, officers of the Survey have rendered considerable assistance by way of information to individuals and companies. Verbal enquiries, numbering over 700, were answered, lectures to groups were given and educational displays were arranged.

PART VII—SCHOOL OF MINES.

(a) Kalgoorlie

The number of students enrolled in 1963 was 365 an increase of 13 by comparison with the previous year. Individual and class enrolment figures indicate quite an increase in the number of students enrolling for Certificate Courses. With the steady increase in standard required for the Associateship Courses and the re-organisation of the Certificate Courses this is to be expected, and it would seem likely that in future there will be an increasing number of students completing the Certificate Courses and not going on to Associateship Courses. This year the number enrolled for Associateship Courses was about the same as for 1962.

The Courses remained very much the same as in 1962. Some changes were made in the Engineering Draftsman's Certificate Course. The Mine Manager's Certificate Course, which for some years had been the academic qualification for the Certificate of Competency in Western Australia, was dropped following a revision of the Mines Regulation Act, and the Mine Manager's Course (Second Class) was introduced. Some changes were also made in the Technician Courses.

Only one student held a Mines Department Scholarship. He completed a satisfactory year's work, but as this was the second year the Scholarship was held it was not available to him for 1964.

Fourteen students held Chamber of Mines Scholarships during 1963; two failed to complete a satisfactory year's work and their scholarships were cancelled; two completed the Courses for which they were enrolled, and the remainder had their scholarships renewed for 1964. Altogether fifteen students have now completed Associateship Courses under the Chamber of Mines programme.

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

It is interesting to record that Mr. W. E. Baldwin, who held a Chamber of Mines Scholarship and who completed the Associateship Course in Egineering at the end of 1963, was awarded an A.E.I. Overseas Fellowship and will leave for England early in 1964. Since 1956 six School of Mines students have been awarded Fellowships.

In 1963, seven students completed Associateship Courses; 12, Certificate Courses; and 2, Technician Courses.

On Wednesday, 29th May, the Annual Presentation Night was held in the Kalgoorlie Town Hall, and the Minister for Mines, the Hon. A. F. Griffith, presented Diplomas, Certificates and Prizes to the successful students. The Guest Speaker was Mr. L. C. Brodie-Hall, General Superintendent, Western Mining Corporation.

Both at the start of the year and at the end of the year the School was without a Librarian and consequently no progress has been made with the development of the Library. It is hoped that this position will change in 1964 with the appointment of a new Librarian.

The School continued to provide the usual services to the public in addition to its teaching activities. The number of samples submitted for assay or mineral determination was 458. This was less than for the previous year, but was still higher than the number submitted in the three years prior to 1962.

The alterations and additions to the Kalgoorlie Metallurgical Laboratory were completed in 1963. Much better working conditions now exist in the Laboratory, but the buildings are still of a temporary nature and the pilot plant is badly placed. This should be housed in a separate building.

During the year new buildings were commenced for the Department of Mathematics and Physics and will be ready for use when the School re-opens in 1964. They are the first brick buildings erected at the School since about 1908.

The School was visited during the year by the Principal Assistant, Design (Architectural Division, Public Works Department) and a sketch plan prepared for an overall plan for future buildings. These included a sketch plan for a building to house the Departments of Mining and Engineering. This is a very urgent need and it is desirable that a start should be made in 1964. Other Departments require additional space and the preparation of an overall plan is essential.

The Advisory Committee met seven times. In October Mr. Mundle resigned because of his retirement from the industry and Mr. R. C. Simpson was appointed by the Chamber of Mines as its representative. Equipment to the value of £2,182 was approved for purchase.

Three reports of investigations and 414 Certificates were issued by the Kalgoorlie Metallurgical Laboratory during the year, and as usual many enquiries were answered by the Senior Research Metallurgist and the staff of the Laboratory.

The Students' Association was active during the year and the usual functions were held.

(b) Norseman.

The number of students enrolled was 68, a decrease of one by comparison with 1962.

Eighteen subjects were taught, and as in previous years use was made of mine workshops for practical work. Some of the subjects taught at Norseman were not available at Kalgoorlie and were introduced to meet the special needs of trade students at Norseman.

The Reg. Dowson Scholarships for 1963 were awarded to H. R. Eyre and R. J. Murphy. The two students awarded the scholarships at the end of 1962 completed a satisfactory year's work in 1963. No other scholarships or prizes were awarded to Norseman students.

During the year minor repairs were made to the buildings, which are generally in good condition.

The Advisory Committee did not meet during the year, but meetings will be resumed in 1964.

PART VIII—INSPECTION OF MACHINERY.

The Chief Inspector of Machinery reports that the number of useful boilers registered at the end of the year totalled 8,297 against 7,957 for the preceding year, showing an increase of 340 boilers under all adjustments.

Of the 8,297 useful boilers 2,338 were out of use at the end of the year, 5,006 thorough and 970 working inspections were made, and 4,989 certificates were issued.

Permanent condemnations total 67 and temporary condemnations 4; 98 boilers were transferred beyond the jurisdiction of the Act.

The total number of machinery groups registered was 48,012 against 45,512 for the previous year, showing an increase of 2,500.

Inspections made total 33,977 and 6,879 certificates were granted.

The total miles travelled for the year were 125,961 against 110,503 miles for the previous year, showing an increase of 15,458. The average miles travelled per inspection were 3.15 as against 3.01 miles per inspection for the previous year.

Four hundred and ninety applications were received and dealt with for Engine Drivers and Boiler Attendants' Certificates, and 441 certificates all classes were granted.

The total revenue from all sources during the year was £17,459 5s. 0d. as against £16,126 18s. 11d. in the previous year, showing an increase of £1,332 6s. 1d.

Total expenditure for the year was £50,266 19s. 6d. against £38,598 2s. 4d. the previous year, showing an increase of £11,688 17s. 2d.

PART IX—GOVERNMENT CHEMICAL LABORATORIES.

The close association of the Government Chemical Laboratories with other Government Departments and with kindred associations was maintained during 1963 and various members of the staff are members of 12 committees connected with the activities of these organisations.

Several major items of equipment have been added to the facilities of the Laboratories in 1963 Building extensions are in progress but it is disappointing that the construction is taking longer than was anticipated.

The total number of registrations in 1963 was 3,532 and the number of samples was 11,421. There was a decrease of approximately 7 per cent. in the number of registrations compared with 1962, but an increase of 7 per cent. in the number of samples.

Samples were received from 16 of the 28 Departments listed in the Public Service List for 1963. The assistance given ranged from the determination of a few parts of selenium in 100,000,000 parts of pasture in connection with white muscle disease of sheep to handling tons of material for advice to industry.

For such a wide range of activities a very broad library is needed, and in 1963 there were 2,303 accessions to the library. In addition to reading in the library there were 1,916 loans from the library to staff members and 296 inter-library loans. This latter facility is of great value as it enables a reduction in the number of journals subscribed for and for which space would have to be found.

Samples received were allocated to the various Divisions of the Laboratories according to the specialised work undertaken by each Division. In a number of cases samples were allocated to more than one Division because for the full elucidation of the problem it was necessary to call on the experience and abilities of different specialists. This co-operation and inter-divisional assistance is further support of the value of one centralised Chemical Laboratory able to call on the specialists in many fields instead of chemical sections in various Government Departments.

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

Agriculture and Water Supply Division.

The physical and chemical examination of a very wide variety of materials for the Department of Agriculture and the examination of waters and problems related to water supply, water treatment and water potability for the Public Works Department, the Metropolitan Water Supply Department and the general public has again been the main function of the Division.

Engineering Chemistry Division.

During 1963 the staff of the Division increased by the creation and filling of two permanent positions, viz., Senior Chemist and Research Officer, and Laboratory Technician Grade 1, and at the end of the year consisted of Divisional Chief, three graduate professional officers and a supporting staff of nine.

Besides advisory service to Government Departments and consultative service to industry, the Division was engaged in investigational work on beach and pilot scale. Though a limited number of original research projects on industrial utilisation of local raw materials was dealt with, a large proportion of the work during the year was done at the request of outside interests, this work being assigned a higher priority than projects initiated by the Division itself.

Food, Drugs, Toxicology and Industrial Hygiene Division.

The greater proportion of the work of this Division in 1963 consisted of chemical examinations for the Departments of Agriculture, Police and Public Health, as well as for the Milk Board of Western Australia and the Swan River Conservation Board, but the usual variety of miscellaneous work was also performed for other departments and for the general public. An unusually large number of samples under the classification of Public Pay, chiefly in connection with medical diagnosis of industrial toxicology.

The staff of the Division was short of one professional officer during the year. As a consequence of building extensions to a portion of the Division, positions have been created for two more chemists and one technician. When the appointments are made this will bring the staff to 15 officers and will greatly facilitate the Division's work.

Fuel Technology Division.

Air pollution examination and prevention have occupied a major part of the time of the Division. A programme of 12 months' dust deposition measurement in the Rivervale and East Perth areas was completed. A report for the Air Pollution Committee has been prepared. The report with the Air Pollution Committee suggests that pollution in the Perth area or anywhere else in the State will not rise to levels which will call for a separate laboratory to deal with sampling and analysis.

Work on light weight aggregates of concrete has gone forward and a number of clays have been examined in conjunction with the Mineral Division to assess brick making and ceramic properties. Other work has been carried on for Government Departments and for industry by the Division.

Industrial Chemistry Division.

In the variety of work carried out by the Division in 1963, the pattern remained in general much the same as in previous years, but there were some slight, but possibly significant, shifts of emphasis. The consultant service continued to grow; more enquiries than ever came from the larger firms and even from the Navy and R.A.A.F.; plastics assumed a more important role in the Division's activities; more time was spent on short-term investigational work.

Mineralogy, Mineral Technology and Geochemistry Division.

The total number of samples examined during the year was 2,678, an increase of about 200 over the previous year. In addition to the Mines Department and its branches, 16 Government Departments or instrumentalities submitted samples for examination. Of these three were Commonwealth, namely, C.S.I.R.O., Civil Aviation and Customs.

Several field trips were made by members of the Division and a number of samples were obtained.

About 150 specimens were added to the Mineral Division Collection during the year, bringing the total number to 3,517. All were of Western Australian origin except 15 from overseas and seven from interstate.

Registration of the 4,949 specimens in the Simpson Collection has been completed and preparation for a card index is well advanced. Both the Mineral Division and Simpson Collections are invaluable to members of the staff, and frequent requests are received from outside interests to examine specimens.

An increasing number of requests are received each year for collections of Western Australian minerals, and in view of this steady growth it has become necessary to limit the number of collections supplied. Twenty-seven sets were made available during 1963.

PART X—EXPLOSIVES.

There has been no change in the staff of the Explosives Branch but under the full impact of the 1961 Act and Regulations some further technical assistance will be required. The Branch's accommodation is not entirely satisfactory and enlargement in the present quarters is impossible.

Explosives of Eastern States origin continued to reach the State in approximately equal proportions by sea to Woodman's Point and by rail with Kalgoorlie as terminus. A trend toward supplementing coastal stocks from Kalgoorlie is expected to assume greater importance on completion of the standard-gauge line. Shipping, however, must retain its function in the supply position, especially as explosives of American manufacture will shortly be marketed here.

As required by law, samples of all new explosives intended for entry to the State were submitted for authorisation. The Inspector visited the New South Wales Explosives Department and spent some 10 days with the explosives chemist and technical staff at Sydney where the materials were already authorised and well known. As a result several were added to the authorised list in Western Australia.

Packaging of explosives and blasting agents in fibreboard and polythene has now almost replaced wood and bituminised paper. The quality of explosives and blasting agents was generally satisfactory, although some consignments of ammonium-nitrate were damaged by water and/or heat.

The usual destruction of unwanted explosives was carried out and some explosives were dumped at sea by the H.M.A.S. *Diamantina* from the R.N.A.R. Depot at Byford.

Several cases of mispossession of explosives by children were dealt with and the criminal use of explosives in wrecking two fishing vessels at North Fremantle was investigated.

Conferences of the Australian Dangerous Goods Transport Committee and of the Australian Port Authorities Association were attended.

A declining trade in fireworks was evident and accidents with fireworks were few.

One case of amateur rocketry was dealt with and the lad concerned allowed to go ahead with certain reservations and safety recommendations. While the curious tinkerer should not be allowed to experiment, an outright ban on properly organised pyrotechnical experimentation could be harsh and retrogressive.

Back-yard making by juveniles of gumnut bombs or other explosive articles using metal pipe to enclose a composition, often containing prohibited admixtures however, must not be permitted.

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

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

Examinations under the Mine Workers' Relief Act during the year totalled 5,498 as compared with 5,760 for the previous year, a decrease of 262. Under the Mines Regulation Act, 2,006 miners were examined, an increase of 194 over the previous year. These were in addition to the 5,498 examined under the Mine Workers' Relief Act. Of the 2,006 men examined under Mines Regulation Act, 1,649 were new applicants and 357 were re-examinees.

The amount of compensation paid during the year under the Miners Phthisis Act was £9,597 1s. 8d. compared with £1,069 11s. 8d. for the previous year.

The number of beneficiaries under the Act was 85 on 31st December, 1963, being seven miners and 78 widows.

During the year the regulations under the Mine Workers' Relief Act were consolidated and it is exjected that these will be printed and available in one volume with the latest consolidation of the Act in 1964.

PART XII—CHIEF DRAFTSMAN.

The staff of the Branch totals 41. Increase of work in the various sections was maintained during the year and the demand for added information and maps of various kinds continued.

The increased scope and spread of mineral investigations has created new problems in connection with land tenure and the affects on other Departments' activities.

Every effort has been made during the year to have as many surveys as possible carried out and five contract surveyors are now making surveys for the Department.

Special attention has been given to the problem of the location and definition of large reserve areas in most difficult country, and the common boundary between two reserves satisfactorily defined.

Work for the Geological Survey has been a major item in the branch activities, and plans and diagrams have been prepared, also, for several other branches.

STAFF.

There has been no slackening in the interest in minerals and 1963 has been another extremely active one for the Department. Examinations of the iron ore deposits in the State have continued with vigour and the search for oil been intensified. Officers of the Department have carried out their duties loyally and efficiently, and I would like to again take this opportunity of thanking them for their efforts.

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

DIVISION II

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Report of the State Mining Engineer for the Year 1963

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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.

Gold production has fallen to 802,860 fine ounces—the lowest figure for several years. Ore treated was also the lowest for some time. With the disappearance of Great Western and Sons of Gwalia from the list of producers such a result is to be expected. The average grade has remained at the satisfactory figure of 5.80 dwts. per ton.

New ventures at Mount Charlotte, Pinnacles and Frances Furness mines give some hope of improvement for the coming year.

All mines are struggling under the burden of rising costs. Technical advances, including hydraulic filling, mechanical handling, steel passes, new drilling techniques and ANFO explosives have so far maintained economic stability but the time is approaching when ore of higher grade will be the only solution except under the most favourable operating conditions.

There has also been a recession in the value of minerals other than gold but this is a reflection of the bad trading conditions in 1963 and there are signs of a recoverey in 1964.

The mining of bauxite at full scale will boost mineral production and a considerable build up in beach sands mining is in progress.

Preparations for the mining of iron ore are well advanced at Koolyanobbing and Tallering Peak and investigation programmes are in hand in other major deposits.

Coal production has been maintained at a regular rate. The outstanding development has been the discovery of substantial tonnages of coal at favourable overburden ratios around the perimeter of the Muja open cut.

The drilling section has operated on a modest basis throughout the year and considerable success has been achieved in rotary drilling for water supplies.

E. E. BRISBANE,
State Mining Engineer.

9th July, 1964.

State Mining Engineer:

Mining activities for the year 1963 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.

District Inspector E. G. Timoney resigned on the 15th March and accepted a similar appointment with the Northern Territory Administration. District Inspector M. R. Simmons resigned on the 12th July to accept a similar appointment with the Department of Mines, New South Wales. Mr. J. J. Zuvich commenced duties as District Inspector of Mines on the 15th July.

ACCIDENTS.

Fatal and serious mine and quarry accidents reported to the Department are shown below. The corresponding figures for 1962 are shown in brackets.

There were 3 (8) fatal and 445 (449) serious accidents.

In gold mines there were 1 (4) fatal and 335 (306) serious accidents. The number of men employed in such mines was 5,297 (5,353). The accident rate per 1,000 men was thus 0.19 (0.75) for fatal accidents and 63.24 (57.16) for serious accidents.

A rigger was killed in a fall at an iron works. There were no fatal quarry accidents during the year under review.

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

TABLE A

Serious Accidents for 1963

Class of Accident	West Kimberley	Pilbara	West Pilbara	Ashburton	Murchison	Gascoyne	Mount Margaret	North Coolgardie	East Coolgardie	Coolgardie	Yilgarn	Dundas	Phillips River	South-West	Collie	Total
Major Injuries—exclusive of Fatal—																
Fractures—																
Head	....	....	....	....	....	....	1	....	....	....	....	....	....	....	....	1
Shoulder	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Arm	....	....	....	....	1	....	1	....	7	....	....	1	....	1	....	11
Hand	....	....	....	....	....	....	....	....	1	....	....	....	1	....	....	2
Spine	....	....	....	....	....	....	....	....	2	....	2	....	....	....	....	4
Rib	....	....	1	....	....	....	....	....	2	....	1	1	1	1	3	10
Pelvis	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Thigh	....	....	....	....	....	....	....	....	1	....	....	....	....	....	....	1
Leg	....	....	....	....	....	....	....	....	4	....	....	2	....	....	1	7
Ankle	....	....	....	1	....	....	....	....	1	....	2	1	1	....	....	6
Foot	....	....	....	....	....	....	....	....	5	....	....	....	....	1	....	6
Amputations—																
Arm	....	....	1	....	....	....	....	....	....	....	....	....	....	....	....	1
Hand	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Finger	....	....	....	....	....	....	....	1	4	....	....	....	....	....	1	6
Leg	....	....	....	....	....	....	....	....	1	....	....	....	....	....	....	1
Foot	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Toe	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Loss of Eye	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Serious Internal	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Hernia	....	....	1	....	....	....	1	....	3	....	....	3	....	....	....	8
Dislocations	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Other Major	2	....	....	....	....	....	1	....	2	....	....	2	....	....	....	7
Total Major	2	....	3	1	1	....	4	1	33	....	5	10	3	3	5	71
Minor Injuries—																
Fractures—																
Finger	....	....	....	....	1	....	....	1	7	1	....	1	....	....	2	13
Toe	....	....	....	....	....	1	....	....	1	....	....	2	....	....	2	6
Head	....	....	....	....	3	....	1	....	5	....	....	....	....	1	....	10
Eyes	....	....	....	....	3	....	1	....	8	....	....	1	....	....	2	15
Shoulder	....	....	....	1	....	1	1	....	4	....	....	1	1	....	2	11
Arm	....	....	....	....	....	....	3	2	8	....	....	....	....	....	2	15
Hand	....	1	....	....	7	....	6	....	59	....	....	8	3	1	5	90
Back	....	....	4	....	1	....	3	1	42	....	3	1	2	3	17	77
Rib	....	....	....	....	....	....	....	....	3	....	....	1	....	....	....	4
Leg	....	....	5	....	....	....	6	....	37	1	2	4	2	1	9	67
Foot	....	....	....	....	1	....	1	....	23	2	....	3	....	....	6	36
Other Minor	....	....	....	2	1	2	1	1	15	....	....	1	....	3	4	30
Total Minor	....	1	9	3	17	4	23	5	212	4	5	23	8	9	51	374
Grand Total	2	1	12	4	18	4	27	6	245	4	10	33	11	12	56	445

There were no serious accidents reported in the year under review in the following Goldfields :—
Kimberley, Peak Hill, East Murchison, Yalgoo, Northampton, North-East Coolgardie, Greenbushes, Broad Arrow.

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	351	....	10	50
Beryl	35	....	....	....
Coal	757	....	56	203
Copper	189	1	13	79
Gold	5,297	1	335	1,459
Gypsum	20	....	....	....
Ilmenite	213	....	1	27
Iron Ore	417	1	2	....
Manganese	28	....	....	....
Oil Exploration	239	....	16	19
Pyrite	99	....	8	23
Tin	117	....	1	1
Other Minerals	47	....	....	....
Rock Quarries	243	....	3	1
Totals	8,052	3	445	1,862

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	....	....	....	....	....	....	....	....	....	....	....	2	....	2
Pilbara	....	....	....	....	....	....	....	....	....	....	....	1	....	1
West Pilbara	....	1	....	....	....	....	....	....	....	7	....	4	....	12
Ashburton	....	....	....	....	....	....	....	....	....	....	....	4	....	4
Peak Hill	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Gascoyne	....	....	....	....	....	....	....	....	....	....	....	4	....	4
Murchison	....	1	....	3	....	2	....	....	....	9	....	3	....	18
East Murchison	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Yalgoo	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Northampton	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Mount Margaret	....	....	....	4	....	2	....	....	....	8	....	13	....	27
North Coolgardie	....	....	....	....	....	....	....	....	....	6	....	....	....	6
Broad Arrow	....	....	....	....	....	....	....	....	....	....	....	....	....	....
North-East Coolgardie	....	....	....	....	....	....	....	....	....	....	....	....	....	....
East Coolgardie	....	1	....	18	....	3	....	....	....	178	1	45	1	245
Coolgardie	....	....	....	1	....	....	....	....	....	....	....	3	....	4
Yilgarn	....	....	....	....	....	....	....	....	....	3	....	7	....	10
Dundas	....	2	....	....	....	....	....	....	....	19	....	12	....	33
Phillips River	....	....	....	....	....	1	....	....	1	6	....	4	1	11
Greenbushes	....	....	....	....	....	....	....	....	....	....	....	....	....	....
South-West	....	....	....	....	....	....	....	....	....	2	1	10	1	12
Collie	....	....	....	4	....	....	....	....	....	43	....	9	....	56
Total for 1963	....	5	....	30	....	8	....	....	1	281	2	121	3	445
Total for 1962	....	5	2	52	....	8	....	....	4	278	2	106	8	449

FATAL ACCIDENTS

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

Name and Occupation	Date	Mine	Details and Remarks
Simpson, William Neillans (Plant Attendant)	26/3/63	Oroya Plant, Gold Mines of Kalgoorlie (Aust.) Ltd., Fimiston	Asphyxiated when buried by a run of ore in the fine ore bin. Assisted by a workmate, he observed the normal safety precautions by wearing a safety belt with rope attached but descended too far below the top of the ore.
Srodzinski, Sydney Charles (Underground Supervisor)	17/9/63	Elverdton Mine, Ravensthorpe Copper Mines N.L., Ravensthorpe	He was buried by a run of ore in a stope when a hung up chute below was fired. Cause of death was asphyxia.
Loffler, John William (Rigger)	14/11/63	Charcoal Iron and Steel Industry, Wundowie	Died from head and other injuries received when he fell 90 feet from the main boiler stack. He was being lowered in a bosun's chair when a rim runner, to which the block and tackle was attached, gave way.

WINDING MACHINERY ACCIDENTS.

Twenty four accidents involving winding machinery were reported during the year and are briefly as follows:

Fatal.—Nil.

Overwinds.—(3). On the 22nd April the driver over-wound the cage at the Paris gold mine. The sheave wheel was fractured and the top rope clip damaged. New sheaves were fitted and the rope was cut and reshod. Temporary lack of concentration by the same driver resulted in another overwind on the 17th May. The sheave wheel was cracked and had to be replaced. The undamaged rope, as a precaution, was cut and reshod.

An overwind at the Sons of Gwalia Ltd. on the 27th December caused cessation of operations a few days earlier than anticipated. Both skips were at the surface and the driver intended to lower the L.H. skip in single gear. He released the brake from the R.H. drum instead of the clutch and when steam was applied the R.H. skip was pulled to the sheave wheel. The cut out operated but failed to stop the skip in time. The sheave wheel was broken and headframe timber badly damaged. This accident marked the finish of operations in the right hand compartment.

Cages Hung Up.—(4). A loose truck retaining bridle caused an empty cage to hang up in the Paris mine shaft on the 22nd April. Some rope coiled on top of the cage and became kinked. The rope was cut and reshod.

Grippers set too fine caused a skip to be hung up in the Victoria shaft on the 5th August. The slight "yo-yoing" effect caused the grippers to act and the rope being lowered coiled up in the shaft and jammed the ascending north skip. The south rope and all attachments on the skip were replaced.

The underground manager's leg was fractured when a skip was hung up in the Elverdton shaft on the 11th August. Subsequent examination showed that a stone became wedged between a skid and the skip which hung up and then dropped.

On the 28th December at Hill 50 the grippers, on the west compartment cage, engaged when the gravity brakes were applied following the failure of the counter current braking. When winding was resumed, after electrical repairs, the slack rope fouled the ascending cage. Both ropes were damaged and had to be replaced.

Cages out of Control.—(2). A cage ran out of control, at the Timoni mine on the 20th March, when the cage was run through the shaft prior to lowering the men on day shift. The brakes, adjusted the previous night, failed to hold the cage in single gear. The badly kinked rope was taken from service.

On the 2nd December a loaded skip ran out of control from the No. 13 level to the bottom at 2,200 feet of the Royal Internal shaft. The skip was about 8 feet short of the tipping position when the driver geared out to shorten up. On starting up again the overload cut out operated but the solenoid trip was not quick enough in applying the main brake. The electric motor required a complete rewind but no other damage resulted.

Derailments.—(10). During the year Central Norseman Gold Corporation reported seven derailments in the Regent shaft and three in the Princess Royal shaft. It would appear that spillage was the cause of the derailments. No one was injured in any of these accidents.

Miscellaneous.—(5) The cage was pulled away when timber was being unloaded at the 700 ft. level of the Croesus shaft on the 6th June. It is thought that one of the timbermen accidently knocked the signal plunger as the driver stated that he received one ring and returned the signal before hoisting.

A trucker left the shaft gate of No. 16 level Oroyal internal shaft open on the 13th June and later accidently knocked a full truck down the shaft. The chasis lodged in the shaft but the tub fell onto the cage which was chaired at No. 19 level.

After lowering rails in the Ivanhoe shaft on the 12th June the platman neglected to close the bonnet of the cage which got caught in a skid joint when the cage was hoisted. Two skids and three centres had to be replaced and the twised cage was removed from service. The platman who was in the cage received bruising and a wrenched shoulder.

A man received a bruised back when a skip was lowered as he was getting out at the 2,800 plat in the Victoria shaft on the 12th September. It was during the first run after crib, at which time the skip at the surface is cleaned of accumulated fine ore, and it is thought that the driver concentrating on the surface skip anticipated the signal to tip it and consequently lowered the other skip. The system of cleaning skips has been changed

A trucker accidentally pushed an ore truck down the Mt. Charlotte shaft on the 31st October after he had neglected to close the shaft gates and alter the rail points. No shaft damage resulted but the cage at the 500 feet level had its hood bent.

PROSECUTIONS.

It was found necessary to prosecute one person during the year. He was fined one pound for failing to use the ventilating equipment supplied.

SUNDAY LABOUR PERMITS.

Four 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 three Sundays at the Reward Shaft, Mt. Charlotte. The permits covered work on rock stresses, sump cleaning, and completion of a pentice.

Bell Bros. Pty. Ltd. was granted a permit to work on one Sunday following a plant breakdown in their Mundijong quarry.

AUTHORISED MINE SURVEYORS.

The Survey Board issued seven certificates during the year.

CERTIFICATES OF EXEMPTION (SECTION 46).

Six certificates were issued, the same number as for the previous year.

PERMITS TO FIRE OUTSIDE PRESCRIBED TIMES (REGULATION 51).

Three permits were issued.

A permit was issued to Hill 50 Gold Mines N.L. to allow for exploration off the Brown Hill shaft. Only one party was employed at this isolated site.

Eclipse Gold Mines N.L. was permitted to fire outside the prescribed times during the exploration of the Pinnacles mine. One party worked each shift at this isolated mine.

One permit was issued to Central Norseman Gold Corporation to provide for two major development headings off the Regent and Royal shafts. Permission was granted because of the isolated sites and the return air did not interfere with other mining operations.

PERMITS TO RISE (REGULATION 64).

Seventy-four permits were issued for 107 rises totalling 12,292 feet. Thirty-three of these rises were constructed using the rising gig method.

ADMINISTRATIVE.

Mines Regulation Act.—A notice published in the *Government Gazette* (No. 29) of the 19th April defined the districts assigned to Workmen's Inspectors of Mines.

Regulation 14 was amended (*Government Gazette*, 30th December) following an increase in wages for Workmen's Inspectors.

New regulations were gazetted, on the 16th December, to provide for the use underground of diesel engines, and regulations concerning underground locomotives were amended in accordance with the new requirements.

Mining Act.—By proclamation in the *Government Gazette* of the 1st March the boundaries of the West Pilbara Goldfield, Pilbara Goldfield and the Nullagine and Marble Bar Districts were altered.

Regulation 205B was amended to include the payment by producers of a royalty of 1s. 6d. per ton on Tripolite. This amendment appeared in *Government Gazette* (No. 53) of the 18th July.

Section 291 was amended to allow for the employment, with the Minister's consent, of Asians and Africans in the mining industry.

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

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

VENTILATION.

All mines throughout the State were inspected during 1963. Dust counts, temperature and air measurements were made in all working places visited. Because of staff shortages, insufficient attention was given to ventilation in the inspection of quarries and beach sand treatment plants in the South West Mineral Field. Conditions in the deep mines continued to show improvement. More secondary fans have been installed and increased use of air water sprays has helped in the suppression of dust.

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	5	362	230
Stoping	10	734	226
Levels	23	378	290
Surface	2	107	294
Totals	40	1,581	247

The average dust count was well below the average of 308 p.p.c.c. recorded in 1962. This reduction was partly due to less dusty conditions underground but the largest proportion was due to the reduced number of visits to centres away from Kalgoorlie. More regular inspections will be made in the West Pilbara and South West in the coming year.

During 1963 all dust samples were counted using a dark field illuminator. Similar equipment has been purchased by all the major mines and this method of counting dust particles is now standard practice throughout the State.

It is with pleasure that I report that for the seventh year in succession there has not been a fatal accident due to the fumes of explosives. Eighteen minor fuming accidents were reported and all were investigated. One man was affected by fumes during slime filling operations. Investigation showed that the stope was inadequately ventilated. A pulp sample containing 70 per cent. solids by weight was analysed and found to contain slightly less than the maximum allowable free cyanide. During filling operations a strong current of air must be maintained and tailings used for filling must not contain more free cyanide than is equivalent to 0.01 per cent. of potassium cyanide.

An assay office employee, suffering from plumbism, was off work for four months. Lead present in the air, of the weighing and mixing of fluxes section, was in excess of the usual accepted standard of 0.15 mgms. per cubic metre. A suitable lead-in-air detector kit is on order so that quick determinations can be made in the various assay laboratories.

Methane gas flows of a minor nature were encountered in the workings of Gold Mines of Kalgoorlie (Aust.) Ltd., and North Kalgurli (1912) Ltd.

A series of tests were conducted, at a drive face on the 1,500 feet level, North Kalgurli (1912) Ltd., to determine the amount of noxious fume released when blasting with an ammonium nitrate-dieselene mixture initiated by detonators only. Twenty-four samples were taken up to 20 minutes after the four test blasts. Results from samples taken five minutes after firing are set out in the table below. Comparison with previous tests indicated that there were no significant changes in the amount of noxious fumes liberated.

CO Explosive Used	CO	CO_2	O_2	Ratio	NO_2
	%	%	%	$CO : CO_2$	p.p.m.
36 lb. Semigel	0·419	0·21	19·96	1 : 2·9	71
33 lb. AN-FO ; 2½ lb. AN. 60 ; No. 6 detonators	0·105	0·54	20·46	1 : 5·1	135
35 lb. AN-FO ; No. 6 detonators	0·143	0·64	20·35	1 : 4·5	206
35 lb. AN-FO ; No. 8 detonators	0·168	0·83	20·24	1 : 4·9	176

Previous results of investigations on fumes appear in the 1956, 1960 and 1962 Annual Reports.

Aluminium Therapy.—The prophylactic treatment with aluminium powder was continued throughout the year. At a conference held late in the year it was decided that a ballot be conducted to decide the future of the treatment. Early in 1964 the mine workers voted in favour of retaining aluminium therapy on the mines.

GROUND VIBRATION.

The Department's Sprengnether Portable Blast and Vibration Seismograph was used on six occasions during the year. Vibrations from blasting operations were measured at the Paringa mine, standard gauge railway cuttings, and quarry sites at Gosnells. Considerable publicity was given to blasting of cuttings near Toodyay but measurement of the vibrations indicated that the furore was unfounded.

GOLD MINING.

The ore treated during the year amounted to 2,770,166 tons as compared with 2,989,653 tons in the previous year. Gold recovered amounted to 802,860 fine ounces as compared with 860,039 fine ounces for 1962.

Grade of ore mined was slightly higher, recovery being 5.80 dwts. per ton as against 5.75 dwts. per ton for 1962.

The calculated value of the gold produced was £12,557,034, which included £12,347 distributed by the Gold Producers' Association from the sale of 701,242 fine ounces of gold at an average premium of 4.92d. per fine ounce.

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

There was a small decrease in the number of men employed in the industry from 5,353 in 1962 to 5,297 in 1963. Average production of ore per man was 523 tons valued at 90.66 shillings per ton as compared with 558 tons valued at 90.10 shillings per ton for 1962. Gold recovery per man averaged 151.56 fine ounces as compared with 160.66 fine ounces in the previous year.

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

Table "D"—Gold Production Statistics.

Table "E"—Classification of Gold Output for 1963 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.
1934	1,772,931	639,871	5,461,004	61·60	12,523	170·69	7·22
1935	1,909,832	646,150	5,676,679	59·45	14,708	175·71	6·77
1936	2,492,034	852,422	7,427,687	59·61	15,698	174·27	6·84
1937	3,039,608	1,007,289	8,797,662	57·99	16,174	174·68	6·64
1938	3,759,720	1,172,950	10,409,928	53·38	15,374	177·50	6·24
1939	4,095,257	1,188,286	11,594,221	56·62	15,216	195·14	5·80
1940	4,291,709	1,154,843	12,306,816	57·35	14,594	213·15	5·38
1941	4,210,774	1,105,477	11,811,989	56·10	13,105	213·70	5·25
1942	3,225,704	845,772	8,840,642	54·81	8,123	209·04	5·24
1943	2,051,011	531,747	5,556,736	54·19	5,079	209·00	5·19
1944	1,777,128	472,588	5,966,451	55·89	4,614	210·18	5·32
1945	1,736,952	469,906	5,025,039	57·86	4,818	213·87	5·41
1946	2,194,477	618,607	6,657,762	60·70	6,961	215·25	5·64
1947	2,507,306	701,752	7,552,611	60·25	7,649	215·25	5·59
1948	2,447,545	662,714	7,132,748	58·28	7,178	215·25	5·42
1949	2,468,297	649,572	7,977,200	64·64	6,800	245·62	5·26
1950	2,463,423	608,633	9,428,745	76·55	7,080	309·83	4·94
1951	2,471,679	648,245	10,042,392	81·26	6,766	309·83	5·25
1952	2,626,612	727,468	11,809,047	89·92	6,394	324·66	5·54
1953	3,169,875	823,331	13,290,100	83·85	6,359	322·84	5·20
1954	3,240,378	861,992	13,492,209	83·27	6,128	313·04	5·32
1955	2,865,048	834,326	13,055,574	91·13	5,845	312·96	5·82
1956	2,870,273	813,617	12,724,923	88·67	5,612	312·80	5·67
1957	2,951,011	849,741	13,304,752	90·17	5,385	313·15	5·76
1958	3,021,072	874,819	13,674,193	90·53	5,352	312·62	5·79
1959	2,959,202	860,969	13,453,808	90·93	5,769	312·52	5·82
1960	3,056,445	869,966	13,593,462	88·95	5,430	312·51	5·69
1961	2,984,458	870,658	13,684,867	91·71	5,337	314·36	5·83
1962	2,989,653	860,039	13,444,861	90·10	5,353	312·66	5·75
1963	2,770,166	802,860	12,557,034	90·66	5,297	312·81	5·80

TABLE E

Classification of Gold Output for 1963 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 ozs.		fine ozs.		fine ozs.		fine ozs.		fine ozs.		fine ozs.	fine ozs.
Kimberley	134	2	26	....	....	....	....	....	....	....	....	160
West Kimberley	....	....	....	....	....	....	....	....	....	....	....	....
Pilbara	1,137	5	627	....	....	....	....	....	....	....	....	1,764
West Pilbara	....	....	....	....	....	....	....	....	....	....	....	....
Ashburton	....	....	....	....	....	....	....	....	....	....	....	....
Peak Hill	48	1	39	....	....	....	....	....	....	....	....	87
Gascoyne	....	1	241	....	....	....	....	....	....	....	....	241
Murchison	304	13	634	....	....	1	4,567	....	....	1	78,196	83,701
East Murchison	140	5	138	....	....	....	....	....	....	....	....	278
Yalgoo	80	1	21	....	....	....	....	....	....	....	....	101
Mount Margaret	398	4	240	....	....	....	....	1	31,344	....	....	31,982
North Coolgardie	594	18	1,205	....	....	1	1,924	1	14,633	....	....	18,356
Broad Arrow	468	8	817	....	....	....	....	....	....	....	....	1,285
North-East Coolgardie	103	3	129	....	....	....	....	....	....	....	....	232
East Coolgardie	1,048	14	418	1	607	2	8,589	....	....	4	520,440	531,102
Coolgardie	739	17	982	....	....	2	8,418	....	....	....	....	10,139
Yilgarn	379	14	670	1	600	1	1,096	1	15,159	....	....	17,904
Dundas	44	2	205	....	....	....	....	....	....	1	102,702	102,951
Phillips River	....	....	....	....	....	1	2,542	....	....	....	....	2,542
South-West	33	....	....	....	....	....	....	....	....	....	....	33
State Generally	2	....	....	....	....	....	....	....	....	....	....	2
Totals	5,651	108	6,392	2	1,207	8	27,136	3	61,136	6	701,338	802,860
Production 1962	5,712	100	6,788	4	3,180	7	23,434	2	39,655	7	781,270	860,039
Production 1961	6,829	109	7,842	5	3,140	8	30,699	2	45,443	7	776,705	870,658
Production 1960	6,507	135	10,565	3	1,922	9	28,512	2	47,574	7	774,886	869,966
Production 1959	7,932	147	8,590	5	4,219	6	9,438	4	75,251	7	755,539	860,969

TABLE F

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

Mine	1963			1962			1961			1960			1959		
	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.	189,248	102,702	10·85	181,834	109,506	12·04	175,124	98,305	11·23	190,679	101,291	10·62	182,996	101,203	11·06
Eclipse Gold Mines N.L.	4,449	4,567	20·53	6,086	6,757	22·21	8,550	7,860	18·39	6,969	7,690	22·07	7,514	12,048	32·07
Gold Mines of Kalgoorlie (Aust.) Ltd.	527,680	141,837	5·38	518,747	140,919	5·43	518,244	152,964	5·90	569,116	150,319	5·28	496,981	134,002	5·39
Great Boulder Pty. Gold Mines Ltd.	450,249	118,520	5·26	450,192	121,628	5·40	452,145	129,388	5·72	448,398	123,875	5·52	454,474	124,041	5·46
Great Western Consolidated N.L.	124,062	15,159	2·44	390,462	61,352	3·14	390,700	58,477	2·99	390,353	63,434	3·25	393,252	67,100	3·41
Hill 50 Gold Mines N.L.	162,558	78,196	9·62	165,698	87,196	10·52	157,196	82,953	10·55	156,844	82,988	10·58	155,471	81,907	10·54
Lake View and Star Ltd.	690,537	168,170	4·87	694,054	172,001	4·96	681,108	166,031	4·88	683,950	165,032	4·83	669,927	162,576	4·85
North Kalgurli (1912) Ltd.	371,967	85,908	4·62	368,350	84,559	4·59	373,795	90,220	4·83	372,053	87,841	4·72	361,344	89,007	4·93
State Batteries	43,944	13,236	6·02	48,154	13,697	5·69	40,673	13,835	6·80	39,219	14,704	7·50	39,048	14,700	7·58
The Sons of Gwalia Ltd.	159,651	31,344	3·93	121,773	25,950	4·26	135,995	32,947	4·85	138,618	32,983	4·76	135,932	33,469	4·92
Timoni (Moonlight Wiluna G.M. Ltd.)	28,914	14,633	10·12	24,493	13,705	11·19	23,871	12,496	10·47	29,880	14,591	9·77	32,229	15,879	9·85
Total	2,753,259	774,272	5·62	2,969,843	837,270	5·64	2,957,401	845,476	5·72	3,026,079	844,748	5·58	2,929,168	835,932	5·71
Other Sources (excluding large Retreatment Plants)	16,907	17,106	20·24	19,810	10,841	10·94	27,057	13,131	9·71	30,366	12,613	8·31	30,034	12,051	8·02
Total (excluding large Retreatment Plants)	2,770,166	791,378	5·71	2,989,653	848,111	5·67	2,984,458	858,607	5·75	3,056,445	857,361	5·61	2,959,202	847,983	5·73
Lake View and Star Retreatment	....	9,222	....	....	9,094	....	....	8,339	....	....	9,187	....	....	9,844	....
State Batteries Tailings Treatment	....	2,260	....	....	2,834	....	....	3,712	....	....	3,418	....	....	3,142	....
Grand Total	2,770,166	802,860	5·80	2,989,653	860,039	5·75	2,984,458	870,658	5·83	3,056,445	869,966	5·69	2,959,202	860,969	5·82

TABLE G

Development Footages Reported by the Principal Mines

Gold or Mineral Field	Mine	Shaft Sinking	Driving	Cross Cutting	Rising and Winzing	Explora-tory Drilling	Total
		feet	feet	ffet	feet	feet	feet
Gold—							
Murchison	Hill 50 Gold Mines N.L.	640	2,917	2,279	1,521	7,983	15,340
	Eclipse Gold Mines N.L.	150	122	100	236	760	1,368
Mount Margaret	The Sons of Gwalia Ltd.	....	2,053	598	2,367	6,785	11,803
North Coolgardie	Timoni (Moonlight Wiluna G.M. Ltd.)	....	593	46	478	....	1,117
East Coolgardie....	Lake View and Star Ltd.	....	23,891	4,164	6,464	31,962	66,481
	Great Boulder Gold Mines Ltd.	....	17,528	1,660	3,837	10,800	33,825
	North Kalgurli (1912) Ltd.	....	14,502	1,539	2,693	27,774	46,508
	Gold Mines of Kalgoorlie (Aust.) Ltd.	6	17,898	5,065	7,587	33,514	64,070
Coolgardie	Paris Gold Mines Pty. Ltd.	80	1,582	152	409	1,166	3,389
Yilgarn	Radio	....	165	57	140	....	362
Dundas	Central Norseman Gold Corporation N.L.	59	5,134	406	4,442	54,407	64,448
	Total in Gold Mines	935	86,385	16,066	30,174	175,151	308,711
Asbestos—							
West Pilbara	Australian Blue Asbestos	....	4,679	....	1,216	4,515	10,410
Pyrite—							
Dundas	Norseman Gold Mines N.L.	....	894	57	550	1,315	2,816
Copper—							
Phillips River	Ravensthorpe Copper Mines N.L.	....	1,984	....	183	825	2,992
West Pilbara	Depuch Shipping and Mining Co. Pty. Ltd.	....	....	....	....	15,074	15,074
	Total in Copper Mines	....	1,984	....	183	15,899	18,066
Iron—							
Pilbara	Mount Goldsworthy Mining Associates	50	....	365	....	4,772	5,187
West Pilbara	Conzinc Riotinto of Australia Ltd.	98	....	100	....	30,039	30,237
South-West	Western Mining Corporation Ltd.	260	....	204	....	3,416	3,880
Yalgoo	Iron Hill Pty. Ltd.	....	....	....	....	5,290	5,290
	Total in Iron Mines	408	....	669	....	43,517	44,594
	Total in all Mines	1,343	93,942	16,792	32,123	240,397	384,597

OPERATIONS OF THE PRINCIPAL MINES.
EAST COOLGARDIE GOLDFIELD.

The total ore treated in this goldfield amounted to 2,040,505 tons with a recovery of 531,102 fine ounces of gold at an average of 5.21 dwts. per ton. This output was equal to 66.2 per cent of the gold production for the State. In the previous year 2,027,855 tons of ore averaging 5.19 dwts. were treated for a recovery of 526,478 fine ounces of gold.

Production in the *Bulong District* amounted to 61 fine ounces from the treatment of 204 tons of ore.

In the *East Coolgardie District* 531,041 fine ounces were recovered from the treatment of 2,040,301 tons of ore. Following are notes on the activities of the principal producers in the district.

Lake View and Star Ltd., with a production of 690,537 tons of ore for a return of 168,170 fine ounces of gold at an average recovery of 4.87 dwts. per ton, was the State's leading producer. Retreatment of tailings yielded an additional 9,222 fine ounces.

The previous year's production was 172,001 fine ounces from the treatment of 694,054 tons plus 9,094 fine ounces from Tailings retreatment.

Estimated ore reserves as at the 1st July were 3,623,800 short tons of an average grade of 4.87 dwts.

Development work completed during the year amounted to 34,519 ft. which was nearly 4,000 feet more than for 1962. A pentice was constructed below the No. 23 level, Lake View shaft in preparation for shaft sinking to 2,800 feet. Plats were established at the Nos. 24, 25, 26 and 28 levels by crosscutting from the internal shaft. Initial connections between the levels were completed by rising on bore holes using the rising gig method. To complete the sink, it now only requires the rises to be stripped to shaft dimensions and timbered.

The hydraulic filling system has been extended and now 17 per cent. of the total ore production is from flat back cut and fill stopes. The system will be complete when a small extension is installed on the Eastern Group of mines. The sands retreatment plant ceased operations towards the end of the year. Loss of production from this plant will be more than offset by increasing the throughput of the mill by 12 per cent. Essential equipment for mill expansion has been installed.

Gold Mines of Kalgoorlie (Aust.) Ltd. produced 141,837 fine ounces from the treatment of 527,680 tons at an average recovery of 5.38 dwts. per ton. Production from the Kalgoorlie group of mines was 138,188 ounces from 517,958 tons which includes 478 ounces from 4,747 tons obtained from te Mt. Charlotte leases. In addition tributers on the Hannas North won 433 ounces from 2,337 tons.

Ore reserves as at the 31st March were 1,012,000 tons at 5.9 dwts. per ton plus 2,559,000 tons of free milling ore averaging 3.2 dwts. per ton.

A close pattern drilling programme of approximately 20,000 feet of diamond drilling at Mt. Charlotte disclosed an ore body containing nearly 2½ million tons above the No. 5 level. Drilling below the No. 5 level indicated that the ore body continues to at least 1,000 feet below the surface. Construction of the free milling plant, with a capacity of 24,000 tons per month, was completed in October. Exploitation of the ore body, some 700 feet long and up to 200 feet wide, will require stoping techniques new to Kalgoorlie. It is intended that diesel powered equipment will be used for underground transport.

Dry fill continued to be placed in old workings in the Perseverance—South Kalgurli section. The use of hydraulic fill in current stoping has permitted the mining of good grade ore in close proximity to filled old workings. Cut and fill mining provided 38 per cent. of the stoping ore treated.

Auriferous pyritic concentrates railed to Perth fertilizer works yielded, in addition to gold, the equivalent of 8,517 tons of sulphur.

Great Boulder Gold Mines Ltd. treated 450,249 tons of ore for a recovery of 118,520 fine ounces of gold, average recovery being 5.26 dwts. per ton. During the previous year 450,192 tons yielded 121,628 fine ounces at an average recovery of 5.40 dwts. per ton.

Ore reserves as at the 3rd June were 2,068,200 short tons averaging 5.35 dwts. per ton.

Development work totalling 23,025 feet was completed on known lode channels. Level development off the Main Shaft Internal was increased following the completion of the ore pass system and provision of adequate ventilation openings. There has been continued expansion in the operation of cut and fill stopes requiring additional underground facilities for the distribution of residue filling material. The progressive deepening of mining operations has necessitated provision for increased air flow through the mine. A low resistance airway between the 800 feet and 1,200 feet levels has resulted from the opening up of the 1,200 level Boundary Caunter Lode shrink stope. This will help reduce the high air resistance in the return airway leading to the surface fan situated some 400 feet east of Edwards shaft.

The calcine washing section, installed during the previous year, effected marked savings in the use of reagents. Four dry cyclones have been erected at the base of the roaster stack.

North Kalgurli (1912) Ltd. treated 371,967 tons of ore for a recovery of 85,908 fine ounces of gold at an average recovery of 4.62 dwts. per ton. In the previous year 84,559 ounces were recovered from 368,350 tons of ore.

Estimated ore reserves as at the 26th March were 2,153,207 tons at 5.26 dwts. per ton. Completed during the year were 14,502 feet of driving, 1,539 feet of crosscutting, 908 feet of rising, 1,785 feet of winzing and 27,774 feet of exploratory diamond drilling. Recent development work has disclosed a downward continuation of the Cutcliffe lode on the Nos. 16 and 17 levels. Encouraging results were also obtained from development of the Brookman and Sommers lodes.

The power plant which was brought into commission in September, 1962 was responsible for a substantial saving in treatment costs.

Increased gold production from *Mount Monger* was brought about by the treatment of 59,882 tons of sands from the Daisy and Haoma mines. The sands yielding 7,960 fine ounces were purchased by Gold Mines of Kalgoorlie (Aust.) Ltd. and carted to Trafalgar for treatment.

The *Daisy* produced 623 fine ounces from 1,180 tons treated at the Kalgoorlie State Battery. Sands from this mine, reported above, amounted to 28,926 tons yielding 3,825 fine ounces of gold. At the *Rosemary* mine 1,445 tons yielded 607 fine ounces.

Three thousand feet of diamond drilling at this mine failed to locate the downward extension of the ore body.

DUNDAS GOLDFIELD.

The production of 102,951 fine ounces of gold from the treatment of 189,842 tons of ore represented 12.8 per cent. of the State's total production. In the previous year 183,719 tons of ore yielded 110,252 fine ounces.

Central Norseman Gold Corporation N.L. treated 189,248 tons for a recovery of 102,702 fine ounces. Gold recovery was at the rate of 10.85 dwts. per ton which was over a pennyweight less than the previous year's grade of 12.04 dwts. per ton when 181,834 tons yielded 109,506 ounces.

Ore reserves are estimated as 609,800 tons at 10 dwts. per ton.

The Crown reef worked from the Regent shaft supplied a little over half the ore treated. Stopes between the Nos. 14 and 32 levels supplied the bulk of this ore. A small tonnage was obtained from the No. 11 level of the Mararoa reef. Some 25,000 feet of surface diamond drilling was completed in 1963 to explore the southern extension of the Crown reef. It is likely that a new shaft will be sunk, south of the townsite, in the near future.

The Princess Royal continues to supply high grade ore mostly from stripping ore discovered in the walls of previously worked stopes. The shaft has been deepened to an underlay depth of 3,852 feet and the No. 22 level plat and launder excavated and timbered.

Surface improvements include the erection of a new lime and cyanide storage shed and the installation of a double decked vibrating screen in the crushing section.

Ore from prospectors at *Beete* amounted to 309 tons which yielded 202 fine ounces of gold.

MURCHISON GOLDFIELD.

171,083 tons of ore were treated in this goldfield for a return of 83,701 fine ounces of gold. This production was equal to 10.4 per cent. of the State's total. In the previous year 94,679 ounces were obtained from the treatment of 174,504 tons.

Gold output from various claims in the *Cue and Day Dawn Districts* amounted to 236 ounces from the treatment of 848 tons. The prospects for 1964 appear a little brighter with Day Dawn Gold Pty. Ltd. shaft sinking, and Eclipse Gold Mines N.L. developing the Pinnacles mine.

In the *Meekatharra District* 496 ounces were recovered from the treatment of 2,978 tons of ore. The most successful producer was the Prohibition with 139 ounces from 1,439 tons.

The *Mount Magnet District* produced 82,968 fine ounces of gold from the treatment of 167,256 tons of ore. The principal producer was *Hill 50 Gold Mines N.L.* with 78,196 fine ounces from 162,558 tons. Average recovery was 9.62 dwts. per ton which was nearly one pennyweight less than the previous year's average of 10.52 dwts. when 87,196 ounces were recovered from 165,698 tons.

The main shaft was deepened 398 feet and the No. 11 level plat cut at 2,463 feet. Rock bolting of the shaft was necessary. Air flow was improved when the No. 11 level plat was connected to drives developed off winzes sunk below the Nos. 8 and 9 levels. In May mining operations were suspended for three weeks whilst modifications were made to the main winding engine. At the same time a larger air main was installed in the shaft, and repairs effected to the treatment plant. Purchases during the year include, a Crydeman shaft mucker, four electric winders 60-100 H.P., and ten battery operated locomotives.

On the Omeara lease the Brown Hill shaft was extended to 442 feet with a level cut at 400 feet and loading station at 430 feet. Level development has commenced to explore the Brown Hill lode.

The ore reserve as at 2nd July was determined as 631,100 short tons at 6.75 dwts.

Eclipse Gold Mines N.L. Production for 1963 was 4,567 fine ounces of gold from 4,449 tons. Operations at the Eclipse mine at Mount Magnet ceased on the 5th October. The company's activities since that date have been concentrated on prospecting the Pinnacles mine situated about 14 miles from Cue. At this mine the underlay three compartment shaft was reconditioned and deepened to 362 feet.

MOUNT MARGARET GOLDFIELD.

The total ore treated in this goldfield was 162,534 tons which yielded 31,982 fine ounces of gold at an average rate of 3.94 dwts. per ton. This output represented 4 per cent. of the State's total. In the previous year 125,371 tons averaging 4.34 dwts. recovery were treated for a yield of 27,186 fine ounces.

The *Sons of Gwalia Ltd.*, in the Mount Malcolm District, ceased operations at the end of the year after 66 years of continuous operation during which time seven million tons of ore returned 2,636,401 fine ounces of gold. Production for the year amounted to 159,651 tons of ore for 31,344 fine ounces; an increase of 37,878 tons and 5,394 ounces on the previous year.

Efforts to lower mining costs by increasing throughput did not give the anticipated relief because of a marked decrease in head grade. Coupled with this setback, the development programme on the 18 and 20 levels failed to produce payable ore.

Development footage for the year amounted to 5,018 feet and comprised 2,053 feet of driving, 598 feet of crosscutting, and 2,367 feet of rising. In addition 6,785 feet of exploratory drilling failed to intersect any worthwhile ore body.

The calculated ore reserve at the 30th June was 194,850 short tons at 4.73 dwts. gold.

With the closure of the mine there has been a decrease in population in the district and it is expected that prospecting will decline even further than that which exists at present. Most of the displaced miners have been absorbed into the mining industry at Kalgoorlie.

At Lake Darlot the *Monte Christo* produced 125 ounces from 1,918 tons. Sands from this low grade lateritic ore assayed 2½ dwts. per ton. The quarry has attained a depth of 30 feet and indications are that the grade of ore is falling off.

Messrs. Hurley and Straw working P.A. 2624C at Freeman's Find recovered 252 ounces from the 191 tons treated. Further good returns are expected in the coming year.

There was no reported production from the *Mount Margaret District* and only 97 ounces from sundry claims in the *Mount Morgans District*.

NORTH COOLGARDIE GOLDFIELD.

Production from this goldfield amounted to 18,356 fine ounces of gold recovered from 34,928 tons of ore averaging 10.5 dwts. per ton. As a comparison the production for the previous year was 17,567 ounces from 32,319 tons averaging 10.9 dwts. The output from this goldfield represented 2.3 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 14,633 fine ounces were obtained from 28,914 tons averaging 10.12 dwts. Ore reserves at the end of June were estimated at 83,000 short tons at 9.08 dwts. per ton.

Stoping was concentrated on the south extension of the ore body between the 200 feet and 600 feet levels. Development footage for the year included 593 feet of driving, 46 feet of cross-cutting, 461 feet of winzing and 17 feet of rising. Another southern extension of the lode is being sought by driving south on the 400 feet level. For most of the year there was a general shortage of labour on this mine which employs 79 men but the position was alleviated by the closure of the Sons of Gwalia.

Crushings from the *First Hit* mine at Menzies yielded 90 fine ounces from 465 tons. The *Goodenough* a consistent producer for several years only returned 48 ounces from 497 tons.

In the *Ularring District* the production was 654 fine ounces of gold recovered from the treatment of 531 tons of ore. The principal producers were the *Oakley* with 283 ounces from 182 tons and the *First Hit* at Morley's Find with 137 ounces from 217 tons.

The *Altona* in the *Niagara District* was responsible for the production of 378 fine ounces from 1,020 tons of ore. The ore was won from remnant mining above the No. 4 level some 600 feet north of the main underlay shaft.

In the *Yerilla District* 2,089 tons were treated for a return of 2,031 fine ounces of gold. Practically all of this production was from the *Yilgangie Queen* with a return of 1,924 fine ounces from 1,469 tons. The Melody shaft was advanced 77 feet to 517 feet inclined depth. The ore block between the 480 and 425 horizons provided most of the ore obtained by the tributers working under agreement with the Western Mining Corporation.

YILGARN GOLDFIELD.

Production for the year was 17,904 fine ounces of gold from 128,812 tons averaging 2.78 dwts. per ton recovery. In the previous year 396,944 tons yielded 65,138 fine ounces at the rate of 3.28 dwts. per ton. This goldfield in 1963 was responsible for 2.2 per cent. of the State's production as compared with 7.6 per cent. for the previous year.

The sudden drop in production was brought about by the cessation of active mining by *Great Western Consolidated N.L.* which was one of the State's leading producers over the past ten years. At the close of the year the only work being undertaken was the mill clean up and the reconditioning of equipment for sale. Great Western production for the year was 15,159 fine ounces from 124,062 tons, average recovery being 2.44 dwts. per ton. Production from the Copperhead at Bullfinch was 9,707 ounces from 80,890 tons. At this mine, mining was confined to several blocks above No. 4 level and a small tonnage from No. 8 level. After completion of salvage operations, the underground workings were closed in July. The powerhouse continues to supply electric power to the towns of Bullfinch, Southern Cross and Marvel Loch. From Frasers, 42,983 tons yielded 5,429 ounces. By June company operations had ceased at this mine, leaving one party of tributers to work several small reefs in the open cut. The Nevoria mine closed early in the year after mining of a block of ore on the No. 4 level was completed and salvage operations carried out.

The *Radio* mine in the Golden Valley centre reported the production of 1,096 fine ounces of gold from 1,092 tons of ore and 845 tons of sands. Ore broken during the year came from the 10 and 11 levels, a vertical depth of about 375 feet. Ore reserves of 3,200 tons will be increased by the intended development at depth.

The *Frances Furness* at Marvel Loch produced 600 ounces from 1,615 tons. There was a sudden drop in grade of ore from this mine as compared with the previous year's output of 1,151 ounces from 1,640 tons. In the coming year Hill 50 G.M.N.L. will be investigating the potential of this property.

At Edwards Find the King Solomon gold mine produced 392 fine ounces from 1,293 tons of ore crushed at Bullfinch and at the State Battery, Marvel Loch.

COOLGARDIE GOLDFIELD.

During 1963, 29,717 tons of ore were treated for a return of 10,139 fine ounces of gold at an average recovery rate of 6.8 dwts. per ton. In the previous year 36,712 tons yielded 11,888 fine ounces.

Gold Mines of Kalgoorlie (Aust.) Ltd., operating the Bayley's mine at Coolgardie, reported the production of 2,962 fine ounces from 6,399 tons of ore. In addition, tributers on the Barbara and Surprise mines produced 254 fine ounces from 986 tons. Developments off Prices Internal shaft were not encouraging and the company's Coolgardie operations were stopped and the leases surrendered.

Paris Gold Mines Pty. Ltd. produced 4,289 fine ounces of gold from the treatment of 13,733 tons of ore from the Paris group and the Mount mine. Included in the production were 2,007 fine ounces of gold in 406 tons exported as a gold-copper concentrate. These concentrates also contained 77 tons of copper and 5,550 ounces of silver valued at £16,949 f.o.b. Esperance. In the Paris mine Fletcher's shoot has been developed at the No. 3 level but development and diamond drilling has failed to locate it at the No. 4 level. Exploratory development of the 112 ft. level of the Mount mine has not been encouraging.

Among the smaller producers in the Coolgardie Goldfield the best returns were from the *Little Nipper* at Ryans Find with 376 ounces from 6½ tons, and the *Federation* on Block 59, Hampton Plains with 110 ounces recovered from 77 tons.

PHILLIPS RIVER GOLDFIELD.

The only producer in this field was *Ravensthorpe Copper Mines, N.L.* with 2,542 fine ounces of gold. 240 ounces were recovered in the mill from 53,867 tons of copper ore, and 2,302 ounces from 5,860 tons of concentrates exported. The concentrates also contained 1,356 tons of copper and 6,886 fine ounces of silver. Most of this production was from the No. 4 sub-level of the Elverdton mine. Mining has ceased at the Beryl and Cattlin mines.

PILBARA GOLDFIELD.

In this goldfield 1,764 fine ounces of gold were recovered from 1,934 tons of ore and the treatment of State Battery sands which yielded 678 fine ounces.

At Bamboo Creek 30 tons of ore from old workings in the *Kitchener* yielded 247 fine ounces of gold. A syndicate has been formed to finance the sinking of a 500 feet shaft for the purpose of exploiting high grade ore intersected some years ago during a Mines Department drilling programme at Bamboo Creek. The *Prince Charlie* at the same centre produced 239 fine ounces from 521 tons crushed at the State Battery, Marble Bar.

The only producer of note in the Nullagine district was the *Barton* with a return of 109 fine ounces from 380 tons.

BROAD ARROW GOLDFIELD.

Total production for the year was 1,285 fine ounces of gold from the treatment of 8,417 tons of ore.

The *Gimlet South* was the leading producer with 430 fine ounces from 6,184 tons. Heavy winter rains prevented work in the open cut and the party had to abandon their plans temporarily and break ore from a block above the 250 level. The *Sleeping Beauty* also at Ora Banda crushed 869 tons for a return of 192 fine ounces.

The State Battery at Ora Banda operated for most of the year and, apart from crushing prospectors' ore, treated 1,600 tons of sands for a recovery of 261 fine ounces.

EAST MURCHISON GOLDFIELD.

In this goldfield, which produced 278 fine ounces from 545 tons, active mining was mostly confined to operations at the *Goanna Patch* on Wildara Station where several parties obtained 142 ounces from 273 tons. The only other producer of note was the *Scheelite* at Barrambie with a return of 45 ounces from 35 tons.

GASCOYNE GOLDFIELD.

The *Star Mangaroon*, with 241 fine ounces recovered from 124 tons treated at the Meekatharra State Battery, was the only producer in this goldfield.

NORTH EAST COOLGARDIE GOLDFIELD.

Production of gold amounted to 232 fine ounces obtained from 610 tons of ore. 284 tons yielding 145 fine ounces were obtained from *Rowes Find* a new area being opened up about 20 miles northeast of Karonie. The reef has been exposed over 200 feet and two parallel reefs show mineralisation.

KIMBERLEY GOLDFIELD.

In this goldfield itinerant prospectors obtained 160 fine ounces of gold from 120 tons of ore, alluvial, and dollied specimens.

YALGOO GOLDFIELD.

Sundry claims in the Warda Warra area produced 80 fine ounces out of the total of 101 fine ounces of gold from 161 tons of ore mined in the Yalgoo Goldfield. Other sources within the State produced 122 fine ounces from 834 tons of ore treated.

MINERALS OTHER THAN GOLD.

The production of minerals, other than gold, for 1962 and 1963 is shown in the table below.

	1962		1963	
Mineral	Tons	Value	Tons	Value
		£A		£A
Asbestos—				
Chrysotile	52·50	1,103	10·13	783
Crocidolite	15,616·95	1,691,933	11,094·57	1,202,002
Barite	494·35	3,116	....	....
Bentonite	485·00	1,213	1,197·00	3,874
Beryl	195·46	32,452	82·03	11,102
Bismuth	0·08	40	....	....
Building Stone	669·00	2,994	559·00	5,777
Clays	54,213·23	62,066	101,300·04	108,135
Coal	919,112·00	1,980,778	902,494·90	1,985,060
Copper—				
Ore and Concentrates	5,277·26	205,399	6,265·75	304,038
Fertilizer Grade	9,275·18	94,569	3,234·75	136,200
Diatomaceous Earth	15·00	300	....	....
Felspar	1,267·00	6,884	992·00	6,985
Fuller's Earth	120·00	480	....	....
Glass Sand	10,325·62	7,708	9,926·09	7,555
Gypsum	51,650·13	87,879	50,808·28	82,467
Ilmenite	205,804·96	911,606	136,879·93	682,067
Iron Ore—				
Exported	1,320,355·00	1,309,643	1,277,613·00	1,266,967
For Pig	72,168·00	1,016,290	73,384·00	1,036,074
Lead Ore and Concentrates	443·03	15,156	184·93	6,535
Leucoxene	788·55	10,767	460·00	5,983
Limestone	36,481·25	24,008	27,895·63	33,618
Lithium Ore—				
Petalite	84·00	403	390·02	3,709
Spodumene	24·15	347	22·00	270
Magnesite	224·01	1,593	6,494·53	44,167
Manganese	89,602·58	1,155,862	39,356·96	512,995
Monazite	950·15	28,544	1,048·81	43,339
Ochre	....	....	21·82	1,278
Phosphatic Guano	68·00	680	16·00	160
Pyrite	49,461·07	356,290	58,472·31	384,875
Quartz Grit	25·00	21	56·00	43
Rutile	874·27	19,906	606·00	18,035
Scheelite	7·35	3,883	....	....
Semi-Precious Stones—Chalcedony	0·20	200	....	....
Silver (fine oz.)....	248,460·93	117,661	203,093·18	116,500
Talc	4,980·95	71,810	4,669·15	71,213
Tantalo/Columbite	19·24	58,874	13·79	23,234
Tin Concentrates	465·44	334,269	576·23	408,023
Zircon	4,132·47	44,343	4,572·85	45,802
TOTAL	....	9,661,070	....	8,558,865

Brief notes on mineral production are given below.

ASBESTOS.

Towards the end of the year a new plant, at the Comet Mine near Marble Bar, commenced operations which resulted in an output of just over 10 tons of chrysotile fibre valued at £783. Estimated output from this mill is 2 tons of fibre per shift. The ore was carted from the Lionel and Soansville centres, mainly from stockpiled material which was obtained during mine development.

Australian Blue Asbestos Ltd. at Wittenoom produced, from 194,463 tons of ore, 11,095 tons of crocidolite valued at £1,202,002. The average number of men employed throughout the year was 336 made up of 185 surface and 151 underground employees.

Output, early in the year, was down as a result of the loss of working faces following the collapse of a section of the Colonial mine in October, 1962. An active programme of stope preparation had to be undertaken to replace faces abandoned for the purpose of providing a buffer pillar between the operating and collapsed sections of the mine. The company experienced a most difficult year which was brought about by the added expenditure on development and reduced sales of fibre. The use of ammonium nitrate-fuel oil explosives has helped reduce production costs.

A start was made with the preparation of a long wall stope to enable tests to be conducted with a proposed method of controlled caving. It is planned to utilize recoverable hydraulic jacks and for this purpose the suppliers technicians have been carrying out investigations in the mine.

BAUXITE.

The first ore from *Western Aluminium N.L.* was railed from Jarrahdale on the 18th July to *Alcoa of Australia Pty. Ltd.'s* refinery at Naval Base. To the end of the year 57,206 tons of ore was delivered to the refinery. 39,915 tons of this was treated for the production of 4,602 tons of alumina valued at £138,060 ex works. This output was stockpiled at the works and will be recorded as production for the year in which it is exported.

The ore is mined from a shallow excavation by a contractor who delivers it to the company's crushing plant which consists of a Wobbly feeder, primary crusher, Jacques hammer mill, and conveyor to two 750 ton capacity bins. Each train load to the refinery is made up of 21 trucks each loaded with 60 tons of bauxite.

BENTONITE.

Bentonite production at Marchagee totalled 1,197 tons valued at £3,874 f.o.r. Production is usually restricted to the summer months when the bentonite can be collected from the flat lake deposits.

BERYL.

Eighty-two tons, containing 924 units of Beryllium oxide valued at £11,102, were obtained from claims in the Pilbara, West Pilbara, Gascoyne, Murchison, Yalgoo, and Phillips River Goldfields. Reduced production as compared with 195 tons for 1962 was brought about by the poor demand at lower prices. Main producing centres were Warda Warra with 566 units, Yinnietharra with 125 units, and Roebourne with 88 units.

BUILDING STONE.

Eighty-two tons of granite suitable for facing stone were reported as being produced at Watheroo; 83 tons of sandstone from Donnybrook, and 394 tons of sawn blocks of spongolite from Ravensthorpe. This production only relates to holdings under the Mining Act and would only represent a small fraction of the State's output.

CLAYS.

Reported clay production from the Metropolitan area, Goomalling, Glen Forrest, Clackline, and Kalgoorlie totalled 101,300 tons valued at £108,135. Output is well in excess of the above tonnage as most of the clay used in the brickmaking industry is obtained from private property and is not reported to this Department.

COAL.

The total output from all mines in the Collie Coalfield was 902,495 tons valued at £1,985,060 at the pit head. Open cut production of 301,561 tons represented 33.4 per cent. of the field's output.

The *Griffin Coal Mining Co. Ltd.* operating the Hebe mine and the Muja open cut produced 534,129 tons. The Hebe with an output of 232,568 tons was the second highest deep mine producer. Some of the production was won from second working in which "bottom coal" is extracted. The main development headings are progressing satisfactorily and are now rising at approximately 1 in 40. The small area of workings on the right hand side of the mine have been sealed off and the coal left will be eventually extracted by open cut methods. Nos. 6 and 7 Left Panel Headings have been broken away and these will provide for five panel districts to the left hand side of the mine after No. 2 Left has ceased production.

The Hebe seam in the east extension area was the source of most of the coal excavated in the open cut. Other seams worked included the Galatea and Eos seams. Overburden removal amounted to 1,085,952 cubic yards in the solid. In October the company commenced exploratory drilling about 2½ miles north east of the Muja open cut. About half a million tons of coal has been proved with an additional 3 million tons indicated.

Western No. 2 mine of *Western Collieries Ltd.* with an output of 288,419 tons was the largest deep mine producer in the field. Two more pump bores were put down, one in the East dip area and the other in No. 4 West district. Water is now pumped from the mine via a total of four bores. The main dip development slants which are now 75 chains from the surface are in good condition and are proceeding according to plan. The seam in this area is 11½ feet thick. Development was stopped in the top east lateral headings when an eroded or vug area was reached. The panels to the rise of these headings have been worked out and the whole of the area permanently sealed off. A new entry into the mine is planned for the coming year.

Western No. 4 mine produced 79,947 tons for the year. There are two districts in the mine with separate ventilating units. In the South Portal district the 11 feet or No. 1 seam is being mined, whereas in the East Portal district the 8 feet or bottom seam is exploited. The bottom seam is approximately 50 feet below the No. 1 seam and is now entered from drifts put down from the open cut. The original workings together with the North portal district have been abandoned. A new screening plant has been installed at the Western No. 2 siding for the purpose of screening Western No. 4 coal.

COPPER.

Ravensthorpe Copper Mines N.L. produced 5,860 tons of concentrate from 53,867 tons of ore containing 135,628 units of copper valued at £290,120 f.o.b. Esperance. In addition 2,542 fine ounces of gold and 6,886 fine ounces of silver were produced. Most of the ore was obtained from the No. 4 sub-level Elverdton mine. Mining has ceased at the Beryl and Cattlin mines.

During the year *Paris Gold Mines Pty. Ltd.* exported 406 tons of gold/copper concentrates containing 77 tons of copper.

Production of copper ore, for use as a trace element in fertilizers, was 3,235 as compared with 9,275 tons for the previous year. Average grade of 14.1% Cu was nearly three times that of the 1962 production. This increase in grade was brought about by the mineral buyers refusing to accept ore containing less than 10 per cent. soluble copper.

Depuch Shipping and Mining Co. Pty. Ltd. commenced production at Whim Creek on the 9th July. Up to the end of the year 15,261 tons of old dump and open cut ore were treated for a recovery of 720 tons of concentrate. 490 tons of this concentrate averaging 28.75 per cent. Cu realised £51,019.

The *Thaduna Copper Mining Co. Pty.* Ltd. continued as a successful producer of cupreous ore. Ore containing 2-3 per cent. copper yielded 1,350 tons of 10.7 per cent. concentrates valued at £36,570. The open cut has reached a depth of 35 feet and is about 20 feet wide at the bottom. An adequate supply of bore water for treatment purposes was maintained and dam water for domestic purposes was sufficient.

Other notable producers of copper ore were *L.T. Parkinson* at Kumarina with 167 tons of 13.74% ore valued at £7,791; *Ashburton Mining Co. Pty. Ltd.* with 82 tons of 19.14% ore valued at £5,914, and the *United Aborigines Mission* at the Warburton Range with 77 tons of 22.32% ore valued at £5,354.

FELSPAR.

Australian Glass Manufacturers Co. Pty. Ltd. reported the production of 992 tons from their quarry at Londonderry. This output was valued at £6,985 f.o.r. Coolgardie. In addition 390 tons of petalite valued at £3,709 were obtained by hand sorting.

GLASS SAND.

Production from the Lake Gnangara deposit amounted to 9,926 tons valued at £7,555.

GYPSUM.

Plaster manufacturers obtained their supplies of raw material from Yellowdine, Lake Brown, Lake Cowcowing and Norseman. This output of 32,547 tons was valued at £20,503. Cement manufacturers obtained 2,844 tons from Nukarni. *Garrick Agnew Pty. Ltd.* exported through Esperance 15,234 tons of Lake Cowan gypsum valued at £58,928. Total production for the year, including 183 tons for agricultural purposes, was 50,808 tons having a value of £82,467.

ILMENITE, LEUCOXENE, MONAZITE, RUTILE, ZIRCON.

Sales of ilmenite totalled 136,880 tons valued at £682,067. Increased output in 1964 is envisaged with the completion of construction of the titanium pigment plant of Laporte Titanium (Aust.) Ltd at Bunbury. Minerals associated with Ilmenite returned £113,159 to the producers.

Western Titanium N.L. at Capel produced 61,661 tons of ilmenite assaying 55.1 per cent. titanium dioxide, 395 tons of leucoxene, 302 tons of monazite, 606 tons of rutile, and 4,343 tons of zircon. Most of this production came from a 5 acre block mined to a depth of 30 feet. Apart from the pilot plant for the upgrading of ilmenite, there has been no alteration to the treatment plant. A new office building has been erected.

Westralian Oil Ltd. produced 33,703 tons of ilmenite assaying 58.8 per cent. TiO_2, 65 tons of leucoxene, 747 tons of monazite, and 230 tons of zircon from the Yoganup deposit. This year the contractor delivered approximately 268,000 tons, containing 37.8 per cent. heavy mineral, to the wet plant. Over 110,000 tons of concentrates were carted to the dry treatment plant at Capel.

Ilmenite Pty. Ltd. operating at Wonnerup near Busselton produced 34,733 tons of ilmenite concentrate assaying 54.6 per cent. TiO_2. The material mined comes from the present beach line just north of the Wonnerup Inlet. Indications are that present operations in this area are limited and it may be necessary to shift the plant to a new site.

Cable (1956) Ltd. produced 6,783 tons of ilmenite averaging 55.1 per cent. TiO_2. It is expected that output will be increased in 1964 when plant modifications and additions are completed.

IRON ORE.

During 1963, 1,277,613 tons of iron ore averaging 63 per cent. Fe were shipped by *Australian Iron and Steel Ltd.* to the Eastern States. Good control of the quarry faces at Cockatoo Island was maintained but some difficulty was experienced in the removal and disposal of a quartzite band which required considerable secondary blasting. At Koolan Island, work proceeded throughout the year with the construction of wharf loading facilities, storage bin, secondary crusher station, workshops and power house. Altogether 14,000 cubic yards of rock were excavated to form the ore storage bin. and 20,000 yards of rock removed to form the crusher station. The average labour force on the two islands was 406 men.

Throughout the year there was considerable activity in the mapping, testing and general appraisal of the iron ore formations of Mt. Newman, Mt. Tom Price, Mt. Brockman, Mt. Goldsworthy, Roy Hill, Deepdale, Tallering, Koolanooka Hills, Mt. Gibson, and Koolyanobbing. At most of the deposits the work of testing was confined to percussion and diamond drilling. At Mt. Tom Price a shaft was sunk to a depth of 98 feet and a crosscut was advanced 100 feet from the bottom. Adits at Mt. Goldsworthy were advanced a total of 365 feet to complete four adits through the main lens of ore. Three adits to test the ore at Dowd's Hill were completed by Broken Hill Pty. Co. Ltd. In the Koolanooka Hills, a shaft on the southern ore deposit was sunk to 118 feet and crosscuts advanced 171 feet east and 33 feet west.

The *Charcoal Iron and Steel Industry* at Wundowie obtained 73,384 tons of ore from the Koolyanobbing deposit. Pig iron produced was 46,038 tons valued at £1,036,074.

LEAD.

Lead concentrate sales amounted to 185 tons valued at £6,535. No lead ore was mined during the year under review but several parties have been investigating old mines in the Northampton district.

LIMESTONE.

Limestone production from holdings covered by the Mining Act, totalled 27,896 tons. Total output of limestone quarried is not available for publication as a large quantity is obtained from private property and is not reported.

Cockburn Cement Pty. Ltd., and Swan Portland Cement Ltd. obtained limestone from South Coogee by surface ripping with bull dozers. Limestone for house foundations was obtained principally from the Wanneroo area where eight quarries are producing. The large amount of rubble produced is used in road construction. At Beaconsfield, limestone is mined, crushed and screened before transport to Wundowie for use by the Charcoal Iron and Steel Industry.

LITHIUM ORE.

Three hundred and ninety tons of petalite were obtained by hand sorting in the felspar quarry at Londonderry. A trial parcel of 22 tons of spodumene from Ravesnsthorpe was shipped to England. Mining of this deposit has been suspended.

MAGNESITE.

Basic Materials Co. Pty. Ltd. exported through Esperance 6,472 tons of magnesite obtained from the Bandalup Creek deposit near Ravensthorpe. The only other production was from Westonia with 22 tons.

MANGANESE.

Exports from Port Hedland totalled 33,156 tons of 51 per cent. Mn ore valued at £433,107 f.o.b. *Westralian Ores Pty. Ltd.* operating at Horshoe in the Peak Hill Goldfield exported through Geraldton 6,201 tons of manganese valued at £79,888.

Manganese production in the Pilbara was at a standstill until late in the year. *Mt. Sydney Manganese Pty. Ltd.* formerly the Northern Mineral Syndicate started carting, from the stock pile in the Mt. Sydney area, during September and active mining began during October. This company exported 22,504 tons and added 13,183 tons to the Port Hedland stockpile. No mining was carried out on Westralian Ores Pty. Ltd's holdings at Skull Springs, their only activity being the export of 10,652 tons from their stockpile at Port Hedland.

OCHRE.

Universal Milling Co. Pty. produced 213 tons of red oxide valued at £1,278 from the Weld Range deposit.

PHOSPHATIC GUANO.

Reported production from the Jurien Bay area was 16 tons valued at £160.

PYRITE.

Norseman Gold Mines N.L. railed 34,893 tons of concentrate, containing 16,709 tons of sulphur, to superphosphate works in the metropolitan area. This output was valued at £278,470 f.o.r. Norseman. This mine has not worked to capacity since the completion of the main shaft in 1953. Ore reserves stand at 2,696,000 tons. Four machinemen broke all the ore required and completed 254 feet of driving during 1963.

Gold Mines of Kalgoorlie (Aust.) Ltd. forwarded to works at Fremantle 23,579 tons of auriferous pyritic concentrate containing 8,517 tons of sulphur valued at £106,405.

QUARTZ GRIT.

Production for local use at Collie was 56 tons.

SILVER.

Silver as a by-product of gold and copper mining amounted to 203,093 fine ounces valued at £116,500.

TALC.

Three Springs Talc Pty. Ltd. reported the production of 4,669 tons from their open cut at Three Springs. It was found necessary to remove a large amount of overburden to uncover suitable talc. An assayer is employed on the mine to check on impurities, if any. Talc crushed at the mine is railed away in bulk and in bags.

TANTALO-COLUMBITE.

Fourteen tons of concentrate, containing 577.44 units of Ta_2O_5 valued at £23,234, were produced in the State during 1963. The main producing centres were Greenbushes with 6.7 tons, Pilbara with 3.9 tons, and Warda Warra with 2.5 tons. Half the Mineral sold was recovered during tin mining operations at Greenbushes. There was not much activity in the other fields because of the poor price being offered for the mineral. During the previous year 19 tons containing units realised £58,974.

TIN.

Production for the year was 576 tons of concentrate containing 392 tons of metal. Tin producers in the Pilbara were responsible for 528 tons of concentrate. Principal producers were *Mineral Concentrates Pty. Ltd.* with 188 tons, *H. V. Leonard* with 99 tons, *Cooglegong Tin Pty. Ltd.*, formerly Northern Syndicate with 96 tons, *J. A. Johnston* with 88 tons and *D. D. Mining Co.* with 37 tons. In the Greenbushes field the *Vultan Syndicate* produced 26 tons and *Austin Bros.* 20 tons.

The principal producers in the Pilbara have been modifying their plants so that increased output can be maintained with lower grade ore which it is now possible to treat, following the high prices now offered for the metal.

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

APPENDIX No. 1.

State Mining Engineer:

REPORT ON DRILLING ACTIVITIES FOR YEAR ENDED 31st DECEMBER, 1963.

The footage drilled by the Mines Department Drilling Section showed a decline of 405½ feet to 8,433½ feet on the total advance for 1962.

Three of the diamond drill rigs were not employed during the period under review though some maintenance and servicing was done on these machines. A commencement was made on modifying the A.3000 plant (M.D. No. 3) to the use of a Kelly for rotary work and was in hand at the end of the year.

A dismantled Failing 750 Rotary rig was purchased from the Commonwealth Bureau of Mineral Resources at a bargain rate and a start has been made to assemble the plant for rotary work.

During the year a trailer mounted auger drill locally manufactured by George Moss & Coy., was purchased by the Section at a cost of £3,500 complete with necessary rods and ancillary equipment. After training a driller this unit took to the field and has been constantly employed since.

The majority of the work undertaken during the year has been for water supply purposes on behalf of the Public Works Department.

Another noteworthy item of equipment added to our establishment in 1963 was the Johnston Formation Tester. This was purchased from Mines Administration Pty. Ltd., Queensland, at a cost of £400. This device is used for testing the content and productivity of selected zones encountered in a drilling well without the expense and loss of time in setting casing. The principle of the tester is to relieve the zone being considered, of the hydrostatic pressure of the column of drilling mud by means of a rubber packer. It opens the formation to atmospheric pressure through the drill pipe and allows the formation water to be sampled inside the drill pipe.

Difficulties in the transport situation have dogged our efforts this year. Most of the drilling has been done in extremely difficult terrain and a request has been made for a wheeled tractor to site the plants. Our other light vehicles have completed their economic lives and are to be replaced. It would be conducive to greater efficiency if a policy of replacing vehicles at a specified mileage of say 60-80,000 miles were adopted.

No. 2 Rig (Failing M.1) drilled 3,638 feet during the year at Eaton, 5 miles north of Bunbury, Capel and Mandurah. The bores at Eaton and Capel were for town water supply purposes and proved to be quite useful for the purpose. The holes at Mandurah were for town water supply purposes. Testing showed an excessive salt content in each case except the last bore which appears to be too far from town.

The actual drilling of these holes takes about one quarter of the time, the balance is occupied in work necessitated by the pumping and testing of the formations. This involved the insertion and withdrawal of lines of casing to the depth of the required aquifers. By means of the Johnston packer the time consumed in testing will be drastically reduced as the laborious insertion and withdrawal of casing is eliminated.

No. 4 Rig (Mindrill A.2000) was occupied on Metropolitan Water Supply dam site investigation projects at Jarrahdale and South Canning where three holes totalling 595 feet were completed. Another interesting assignment begun by this rig was the testing of the reinforced concrete foundations of the new Government offices at King's Park Road and Havelock Street. Ten holes totalling 49 feet were completed. The cost per foot of these holes would be something above £10 per foot due to complete loss of diamonds when penetrating the steel reinforcement. Total footage done by this machine was 644 feet.

No. 7 Rig (Mindrill F.20). Five short holes totalling 336 feet were drilled by this machine investigating potential dam site conditions in the Hills. This rig was hired to a contractor, Mr. A. Anderson, for some copper exploration at Kumarina.

No. 8 Rig (Mindrill E500) was returned to Welshpool from the Sons of Gwalia mine to whom it had been hired since February, 1961. No record of its footage has been received. It was then hired to Shark Bay Salt Coy., at Shark Bay where some drilling was done on foundation work.

No. 9 Rig (Gemco). 1,059 feet of drilling investigating ground water resources in the Hills area round Kalamunda, Carilla and Karragullen were done by this machine. It was then shifted to Dandaragan where 141½ feet were drilled investigating potash occurrences.

HYDROLOGICAL SECTION.

A programme investigating the ground water resources of the Gnangara area was commenced by the Geological Surveys. In this connection both our percussion rigs have been engaged.

Ruston Bucyrus Rig No. 1 drilled 531 feet. Some work was done by this plant in pulling casing on Mandurah No. 2 Hole which the Failing could not handle.

Percussion Rig No. 2 drilled 2,081 feet in 9 holes at Gnangara. At the beginning of the year a bore at Watheroo was deepened three feet and completed at a depth of 114 feet and showed a salt content of 120 grains per gallon suitable only for stock purposes. Work was also done by this rig in cleaning out a bore constructed by this department on the Agricultural Research Station at Badgingarra.

The policy of assistance to drillers and contractors engaged in developing the potential resources of the State was continued during the year. A list hereunder shows the firms and individuals who have benefited from this system during the year.

Geo. Wimpey & Sons—Rail standardisation.
Baker & Sons—Balcatta bore.
Australian Blue Asbestos—Wittenoom asbestos.
P.W.D.: Harbours and Rivers—Geraldton Harbour.
Shark Bay Salt Coy.—Plant foundation.
Westphal Bros.—Country bores.
Ingersoll Rand—Country bores.
S. J. Campbell—Country bores.
Perron & Sons—Iron ore exploration.
Western Machinery Coy.—Tool fabrication.
E. Scott & Coy.—Country bores.
Mindrill Ltd.—Diamond bits.
Wapet—Core barrel.
P.W.D.: Hydraulics—Canning dam raising.
A. W. Brewer—Drill parts.

U.S. Navy—N.W. Cape project.
Swan Boring Coy.—Country bores.
Darling Range Boring Coy.—Country bores.
State Electricity Commission—Collie (casing).
Metropolitan Water Supply—Guildford bridge.
Dresser Sie—Rock bits (Hunt oil).
Broken Hill Pty.—Garden Island limestone.
Main Roads Department—Road foundations.
Western Mining Corporation—Equipment.
Heinsen—Equipment.

The servicing of the plant and equipment taken out by the above firms occupies a considerable proportion of the time of the depot here.

However the rents charged should be a considerable source of income as an offset to the costs involved.

A table hereunder shows the salient features of the year's drilling.

J. HADDOW,
Inspector of Mines (Drilling).

1st April, 1964.

TABLE SHOWING FOOTAGE DRILLED FOR YEAR ENDED, 31st DECEMBER, 1963

Rig No.	Machine	Place	Purpose	Footage	Total	Basis	Remarks
2	Failing	Eaton	Water Supply	750		Contract	All bores tested
		Capel	Water Supply	292	....	....	All bores tested
		Mandurah	Water Supply	2,596		....	All bores tested
					3,638		
4	Mindrill A.2000	Jarrahdale	Dam Foundations	192			
		South Canning	Dam Foundations	403		Wages	
		Perth	Foundation Building	49		....	Reinforced Concrete
					644		
7	Mindrill F.20	Jarrahdale	Dam Foundations	184		Wages	
		Wongong	Dam Foundations	152			
					336		
			AUGUR				
9	Gemco	Kalamunda	Water Supply	1,059		Wages	
		Dandaragan	Potash resources	141½			
					1,200½		
			PERCUSSION RIGS				
1	R.B.22R.W.	Gnangara	Water Supply	389		Wages	Rig overturned
			Observation Holes	142			
					531		
2	R.B.22R.W.	Watheroo	Water Supply	3		Wages	
		Badgingarra	....	....			Cleaning out Bore
		Gnangara	Water Supply	2,081			
					2,084		
					8,433½		

APPENDIX No. 2.

November 27, 1963.

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 1963.

Mining Law Examination:

An examination in Mining Law for the Mine Manager's Certificate of Competency was held on 8th April, 1963. Details were as follows:—

Entries	13
Admitted	12
Passed	7
Failed	5

The names of the successful candidates were—

Banks, F. R.
Hug, R. L.
Letts, I. R.
Loxton, I. W.
McNally, R. T.
Powell, P.
van der Hoek, B. J. D.

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

Underground Supervisors' Examination:

The written examination for the Underground Supervisor's Certificate of Competency was held on 10th September, 1963, and attracted applicants from the following centres—

Kalgoorlie	10
Leonora	1
Mt. Magnet	1
Norseman	4
Ravensthorpe	1
Wittenoom	1
	18

The eighteen (18) applicants were admitted and sat for the examination with the following results—

Examined	18
Passed	11
Failed	7

Certificates of Competency were issued to the successful candidates whose names were as follows:

Abatematteo, G. J.—Kalgoorlie.
Chamberlain, H. I.—Kalgoorlie.
Gianni, E.—Kalgoorlie.
Hindmarsh, J. J.—Norseman.
Hodge, F.—Kalgoorlie.
Lee, J. H.—Kalgoorlie.
Matheson, W. R.—Leonora.
Morton, B. P.—Norseman.
McNair, H.—Mt. Magnet.
Radisich, M.—Kalgoorlie.
White, A. A.—Kalgoorlie.

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

Mine Managers' Certificates:

Ten applications for Mine Manager's Certificates were received during the year, details of applications are as follows:—

Under the Old Mines Regulations Act

The name of the successful applicant was: McGushin, P. J.

Two further applications under these Regulations were deferred until 1964.

Under the New Mines Regulations Act

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

Burrows, H. L.
Henderson, G. A.
Simmons, M. R.
van der Hoek, B. J. D.
Boylen, R. S.
Ibbotson, A. W.
Shanahan, J. P.

There have been no applications for Second Class Mine Managers' Certificates to date.

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' Certificates of Competency:—

Kalgoorlie.
Norseman.
Leonora.
Ravensthorpe.
Mt. Magnet.
Wittenoom.

(Sgd.) C. S. MASON,
Secretary, Board of Examiners.

Mines Regulation Act, 1946

Examination for Mine Manager's Certificate of Competency

MINING LAW

April, 1963

Time Allowed—Three (3) Hours

Attempt Six (6) Questions from Section A

Attempt Four Questions from Section L

Candidates should note—

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

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

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

SECTION A

(Mines Regulation Act and Regulations)

Attempt Six (6) Questions from this Section

Do Not Attempt More than Six (6) Questions from this Section

Marks Allowed are ten (10) Per Question

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

1. (a) The placement of winzes and the arrangements of pipes, valves, hoses and ladders during winze sinking operations.
   (b) Rises.
2. (a) Construction of an underground dam.
   (b) Penthouses.
   (c) Unconsciousness resulting from the inhalation of fumes.
3. (a) Men working alone.
   (b) Firing in winzes.
   (c) Platmen and bracemen.
4. (a) Handling of explosives underground.
   (b) Misfires.
5. (a) When a mine is to be abandoned.
   (b) Use of the English language in and about a mine.
6. Action of a mine manager:—
   (i) On assuming control of a mine.
   (ii) With regard to the Mines Regulation Act and Regulations.
   (iii) When a "serious" accident occurs on the mine.
7. Raising or lowering of men or material in a cage, skip, kibble or similar appliance.
8. (a) Crib places.
   (b) Safety provisions on locomotives.
   (c) Who shall use a locomotive underground.
   (d) Who may make mine plans for submission to the Mines Department.

SECTION B

(MINING ACT AND REGULATIONS)

Attempt Four (4) Questions from this Section

Marks Allowed are Ten (10) Per Question

9. (a) An application has been made for a gold-mining lease. Have miners the right to search for alluvial gold on this land?
   (b) If alluvial gold is found what may be the effects on the original application?
10. (a) When must labour conditions be first complied with on:—
    (i) A Gold Mining Lease.
    (ii) A Mineral Lease.
    (iii) A Mineral Claim.
    (b) The approval of the application for a lease confers certain rights on the lessee. How, if at all, does a G.M.L. differ in this regard from Mineral Lease.
11. (a) What are the differences, if any, between the following:—
    (i) Tailings Area.
    (ii) License to Treat Tailings.
    (b) If a lease is to be surrendered what action must the Lessee take if he wishes to protect any tailings on the Lease.
12. (a) What is necessary before a miner may search for minerals on private land?
    (b) What provisions does the Act make for the payment of compensation to the owner and/or occupier of private land by an applicant for a lease or claim?
13. (a) How would you mark out and make application for a gold-mining lease?
    (b) If certain leases are amalgamated what labour is required to satisfy normal labour covenants?

Western Australia.

Mines Regulation Act, 1946-61.

Examination for Certificate of Competency as Underground Supervisor.

MINING.

September, 1963.

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.

1. An ore body is 200 feet long, 8 feet wide, and dips at 65° to the west.

A leading stope has been broken and the broken ore cleaned out.

Explain in detail how you would prepare this section for stoping by slime filling.

or

Explain in detail how you would prepare this section for stoping by dry filling.

Sketches are required.

2. Draw sketches giving details of ventilation and access in two of the following:—

(a) A shrink stope which has advanced 50 feet above the lower level.

(b) A cut and fill stope which has advanced 50 feet above the lower level.

(c) A fairly flat pillar supported stope which has advanced 80 feet from the access level.

Sketches should cover stopes at least 120 feet long.

3. Explain in detail your procedure in charging and firing any two of the following:—

(a) A drive face using AN/FO and safety fuse.

(b) A rise 50 feet up, using AN/FO and electric detonators.

(c) A winze face, 60 feet down using 60 per cent. AN "Gelignite" and electric detonators.

(d) A stripping face on a plat adjacent to a working shaft using electric detonators with any explosive.

Details of hole pattern are not required.

4. You are the Underground Supervisor on afternoon shift: What do you look for in regard to safety, and what action do you take when you visit a drive face and the miner reports that a mishole containing AN/FO has been found.

or

You are the Underground Supervisor on afternoon shift. A winze is being sunk on both day and afternoon shifts. The day shift miner reports that apparently two holes have "missed". He had charged with 60% AN Gelignite.

Give details of the action taken by you.

5. Two levels have been driven, one 200 feet above the other, on an orebody which is nearly vertical.

Describe in detail:

(a) How you would connect the levels by rising

or

(b) How you would connect the levels by winzing.

Sketches showing details are required.

6. Describe fully, the precautions you would take for safe working in the following:—

(a) Repairing a section of shaft skids.

(b) Repairing a grizzley on a level, when the grizzley is part of a main ore pass system.

(c) Freeing an ore pass which has become "hung up".

7. You are the platman on a vertical shaft on afternoon shift. It is necessary to carry out the following work:—

(a) Lower two timber stulls each 15 feet long and 12 inches diameter from the surface to No. 10 level.

(b) Lower a full load of pass logs from the surface to No. 12 level.

(c) Shift ten 2 in. pipes each 20 feet long from No. 12 level to No. 6 level.

You have a braceman and other assistants available. There is adequate handling room on the plats. The cage is 8 feet high.

Explain how you would undertake this work and all the safety precautions you would take.

8. A cross cut 7 feet by 5 feet is to be driven a distance of 500 feet. On the same level there is an opening to an empty stope where mullock can be disposed.

The stope measurements are 100 feet long, 8 feet wide and 60 feet deep.

(a) How many tons of mullock will be broken to complete the crosscut.

(b) How many tons of mullock can be tipped into the stope?

(12 c. ft. of solid mullock equals 1 ton; 20 c. ft. of broken mullock equals 1 ton.)

Western Australia.

Mines Regulation Act, 1946-61.

Examination for Certificate of Competency as Underground Supervisor.

MINING LAW.

September, 1963.

Time Allowed Two (2) Hours.

Read the Examination Paper Carefully.

Answers must be written in ink.

All questions need not be attempted. Answer as many as you can in the time available. Good answers are more important than the number of questions answered.

What is required by the Mines Regulation Act or the Regulations made under that Act concerning the following:—

(1) Clearing passes and chutes.

(2) Recharging holes.

(3) Recirculation of air.

(4) Safety belts in winzes.

(5) Safety provisions for locomotives.

(6) Men travelling in a skip.

(7) Precautions necessary when repairing shafts.

(8) Who may use explosives underground.

(9) Raising or lowering tools or equipment in a shaft.

(10) Ladders in shafts.

(11) Place where serious accident has occurred.

(12) Who may fire electrically.

(13) Gates to cages.

(14) Who may take charge of a hoist underground.

(15) Men working alone.

(16) Signalling in winzes.

(17) Working party's magazines.

(18) Safety helmets.

(19) Length of fuses.

(20) Stoppings and doors underground.

Index to State Mining Engineer's Annual Report for 1963

DIVISION III

Report of the Superintendent of State Batteries—1963

1963

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 1963, gold, tin, tungsten, lead, copper and tantalite ores to the value of £18,509,405 have been treated at the State Batteries. Included in the above amount is gold premium of £7,048,325 and premium paid by sales of gold by the Gold Producers Association Ltd., of £43,162. £18,076,045 came from 3,417,388 tons of gold ore, £94,793 from 81,894 tons of tin ore, £18,850 from 3,960 tons tungsten ore, £301,751 from 28,695½ tons lead ore, £5,966 from 220½ tons of copper ore and £12,000 from 95 tons of tantalite ore.

During the year 43,944¼ tons of gold ores were crushed for 15,618 oz. bullion, estimated to contain 13,236 oz. fine gold, equal to 6 dwts. per ton. The average value of sands after amalgamation was 3 dwts. 5 grs. per ton, making the average head value 9 dwts. 5 grs. per ton. Cyanide plants produced 2,260 oz. fine gold, giving a total estimated production for the year of 15,496 oz. fine gold valued at £242,568.

The working expenditure for the year for all plants was £214,774 and the revenue was £35,710 giving a working loss of £179,064 which does not include depreciation or interest. Since the inception of State Batteries, the Capital expenditure has been £813,429 made up of £633,817 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 £22,687 compared with £21,028 for 1962.

The working expenditure from inception to the end of 1963 exceeds revenue by £1,875,182.

Under Secretary for Mines:

For the information of the Hon. Minister for Mines, I have the honour to submit my report on the operations of the State Batteries for the year ending 31st December, 1963.

Crushing Gold Ores.

One 20 head, five 10 head, and ten 5 head mills crushed 43,944¼ tons of ore made up of 597 separate parcels, an average of 73.61 tons per parcel. The bullion produced amounted to 15,618 ozs. which is estimated to contain 13,236 ozs. of fine gold, equal to 6 dwts. of gold per ton of ore.

The cost of crushing, including administration was 73s. 4d. per ton, an increase of 8s. 5d. per ton compared with the previous year when 48,153¾ tons were crushed at a cost of 64s. 11d. per ton.

The average value of the ore after amalgamation, but before cyanidation was 3 dwts. 5 gr. Thus the average head value of the ore was 9 dwts. 5 grs. which is 15 grs. more 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	19,200¼	43·7
1 dwt. 18 grs. to 2 dwts. 8 grs. per ton	3,985¾	9·1
Under 1 dwt. 18 grs. per ton	20,626¼	46·9
Refractory	132	·3
	43,944¼	100·0

Cyaniding.

Eight plants treated 17,935 tons of tailings from amalgamation for a production of 2,260 fine ozs. of gold worth £35,441. The average content was 4 dwts. 7 grs. before cyanidation, while the residue after treatment averaged 1 dwt. 17 grs. The theoretical extraction was therefore 60 per cent. The actual extraction was 59 per cent.

The cost of cyaniding was 54s. 10d. per ton, an increase of 9s. 9d. per ton on the previous year, when 19,760 tons were treated at a cost of 45s. 1d. per ton.

Estimated Overall Recovery.

Figures for estimated recovery are:—

	Content Fine oz.	Per Ton Crushed Dwt.	Per Ton Crushed Grs.	Per cent.
Head Value	20,299	9	5	100
Amalgamation Recovery	13,236	4	5	65·2
Cyanidation Recovery	2,260	1	1	11·0
Total Recovery	15,496	5	6	76·2

Treatment of Ores Other than Gold.

Lead Ores.

No treatment for the year.

Tin Ore.

The Marble Bar Battery crushed 76 tons of ore for 5 cwt. 3 qrs. 19 lb. of concentrates valued at £216.

Tantalite Ore.

During the year the Cue Battery crushed 24 ton of ore for 9 cwt. 3 qr. 8 lb. of concentrates valued at £1,400.

Agriculture Copper Ore.

A trial parcel of 4½ tons of Copper ore was crushed at the Northampton Battery. The concentrates were of no value.

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

	1963 £	Grand Total £
Par Production—		
Crushing	56,224	8,812,051
Cyanidation	9,728	2,172,507
Gold Premium—		
Crushing	150,592	5,505,039
Cyanidation	25,713	1,543,286
Open Market Premium—		
Crushing	271	32,462
Cyanidation	40	10,700
Total Gold Production	242,568	18,076,045

OTHER ORES REALISED

Tin—		
Ores	216	94,221
Residues	*Nil*	572
Tungsten Concentrates	*Nil*	18,850
Agricultural Copper Ore	*Nil*	5,966
Lead Concentrates	*Nil*	301,751
Tantalite Concentrates	1,400	12,000
Total Other Ores	£1,616	£433,360
Grand Total	£244,184	£18,509,405

Financial.

	Tons	Expenditure	Receipts	Loss
		£	£	£
Crushing (Gold Mills)	44,044¼	161,382	21,389	139,993
Crushing (Northampton)	4½	4,227	10	4,217
Cyaniding	17,935	49,165	14,311	34,854
	....	214,774	35,710	179,064

The loss of £179,064 is an increase of £18,872 on the previous year. It does not include depreciation and interest on capital.

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

	£	s.	d.
Boogardie—Renewal of Electrical Wiring	867	15	6
Cue—Renewal of Electrical Wiring	241	8	2
Kalgoorlie—Trailer, Rock Drill, Post Hole Digger	509	2	6
Meekatharra—			
Renewal of Electrical Wiring	28	16	2
Renewal of Cyanide Plant	1,337	17	0
Norseman—Renewal of Cyanide Plant	3,419	13	8
Ora Banda—Renewal of Cyanide Plant	265	12	8
Sandstone—Renewal of Electrical Wiring	715	16	0
	£7,386	1	8

Cartage Subsidies.

	Tons	Cost
Ore carted to State Plants	11,681½	£6,171

Comparative figures for the last three years are:—

Year	Tons Crushed	State Plants: Tons Subsidised	State Plants: Per cent. Subsidised	State Plants: Cost	Private Plants: Tons Subsidised	Private Plants: Cost	Private Plants: Total Cost
				£		£	£
1961	40,673	13,402	32·9	6,347	298	184	6,531
1962	48,153¾	17,639	36·6	9,334	*Nil*	*Nil*	9,334
1963	44,044¼	11,681½	26·5	6,171	24	5	6,176

Administrative.

Expenditure amounted to £22,686 13s. 4d., equivalent to 7s. 2d. per ton of ore crushed and cyanided, compared with an expenditure of £21,027 13s. 4d., 6s. 1d. per ton, for 1962.

	1962 £	s.	d.	1963 £	s.	d.
Salaries	12,179	5	1	13,788	9	5
Pay Roll Tax	3,310	7	3	3,402	6	11
Workers' Compensation	3,969	4	4	3,805	16	3
Travelling and Inspection	889	0	9	725	0	11
Sundries	679	15	11	964	19	10
	21,027	13	4	22,686	13	4

Staff.

Manager J. G. Young died suddenly in August. Graham Young had been a loyal and capable State Battery Officer for many years. He had worked at most State Batteries and will be missed by his many friends throughout all goldmining districts.

Manager Crew was transferred from Coolgardie to Cue.

Manager Steel was transferred from Marvel Loch to Coolgardie.

Manager Jenkin was transferred from Ora Banda to Marvel Loch.

General.

There was a reduction of 4,210 tons of gold ore crushed compared to 1962, but the average grade of ore was higher. Crushing costs rose considerably, being 8s. 5d. per ton higher. It should be noted however that 1962 costs were 6s. 6d. per ton lower than in 1961, so the 1963 costs were 1s. 11d. per ton higher than 1961.

Cyaniding results were poor compared with 1962. The tonnage treated was 1,825 tons less, treatment costs rose by 9s. 9d. per ton, and the recovery was lower. The lower tonnage and higher costs were mainly caused by exceptionally wet weather, which seriously interfered with tailings treatment at most Batteries. Flooding caused some gold losses, but the low recovery, particularly at Marble Bar and Bamboo Creek, was caused by the refractory ore, from which high recovery cannot be made by leaching.

No lead ore was crushed at the Northampton Battery. The price of lead rose considerably during the latter part of the year, and at the end of the year several parties, were considering reworking mines. A considerable tonnage of lead ore is likely to be crushed in 1964, and in preparation for this, necessary maintenance was done late in 1963.

A curvilinear table was installed at Marble Bar to allow tin ore to be crushed. Several trial parcels, making a total of 76 tons were crushed. The results were encouraging and an increased tonnage in 1964 is expected.

K. 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, 1963

Battery	Tons Crushed	Gold Yield Bullion ozs.	Value per Ton in shillings	Total Value without Premium
				£
Boogardie	249·00	130·90	37·85	471·24
Coolgardie	5,528·00	1,786·90	23·27	6,432·84
Cue	848·25	162·00	13·75	583·20
Kalgoorlie....	9,635·75	3,650·30	27·27	13,141·08
Lake Darlot	2,385·25	613·95	18·53	2,210·22
Leonora	711·00	284·10	28·77	1,022·76
Marble Bar	1,235·25	913·70	53·25	3,289·32
Marvel Loch	3,120·25	1,440·25	33·23	5,184·90
Meekatharra	3,052·75	892·60	21·05	3,213·36
Menzies	3,932·50	1,324·05	24·24	4,766·58
Norseman	1,047·75	415·00	28·52	1,494·00
Nullagine	698·25	216·75	22·35	780·30
Ora Banda	8,325·50	1,156·60	10·00	4,163·76
Peak Hill	817·00	93·30	8·22	335·88
Sandstone	234·75	57·50	18·06	207·00
Yarri	2,123·00	2,479·85	84·10	8,927·46
Total	43,944·25	15,617·75	25·58	56,223·90

SCHEDULE No. 2

Number of Parcels Treated, Tons Crushed and Head Value for the Year Ended 31st December, 1963

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.
7	Boogardie	249	130	18	110	19	....	16	122	16	9	20	2	1	9
89	Coolgardie	5,528	1,786	18	1,514	8	722	6	2,236	14	8	2	1	14	4
16	Cue	848¼	162	....	137	6	175	12	312	18	7	9	1	11	4
108	Kalgoorlie	9,635¾	3,650	6	3,093	12	1,288	18	4,382	10	9	2	1	18	7
23	Lake Darlot	2,385¼	613	19	520	6	327	18	848	4	7	2	1	10	1
20	Leonora	711	284	2	240	16	101	19	342	15	9	15	2	0	10
23	Marble Bar	1,235¼	913	14	774	7	529	9	1,303	16	21	2	4	9	7
58	Marvel Loch	3,120¼	1,440	5	1,220	12	557	17	1,778	9	11	9	2	8	4
59	Meekatharra	3,052¾	892	12	756	10	1,128	9	1,884	19	12	8	2	12	5
49	Menzies	3,932½	1,324	1	1,122	3	586	2	1,708	5	8	16	1	16	10
30	Norseman	1,047¾	415	....	351	14	268	....	619	14	11	19	2	10	1
10	Nullagine	698¼	216	15	183	14	88	17	272	11	7	19	1	13	1
66	Ora Banda	8,325½	1,156	12	980	4	1,063	17	2,044	1	4	22	1	0	11
6	Peak Hill	817	93	6	79	2	37	7	116	9	2	20		12	1
2	Sandstone	234¾	57	10	48	15	10	1	58	16	5	....	1	1	3
31	Yarri	2,123	2,479	17	2,101	13	164	8	2,266	1	21	8	4	10	7
597		43,944¼	15,617	15	13,236	1	7,062	16	20,298	17	9	5	1	19	1

Average Tons per Parcel .... 73·61
Average Yield by Amalgamation per ton (Fine Gold) .... 6 dwts.
Average Head Value of Tailings .... 3 dwts. 5 grains.

SCHEDULE No. 3

Segregation of Tailings Produced according to Value, Year Ended 31st December, 1963

Battery	Payable			2 dwts. 8 grains to 1 dwt. 18 grains			1 dwt. 18 grains and under			Refractory			Total		
	tons	oz.	dwts.	tons	oz.	dwts.	tons	oz.	dwts.	tons	oz.	dwts.	tons	oz.	dwts.
Boogardie	8	3	15	....	....	....	241	8	1	....	....	....	249	11	16
Coolgardie	2,304½	517	8	131¼	13	1	3,058	176	13	34¼	15	4	5,528	722	6
Cue	435	142	12	150	14	11	263¼	18	9	....	....	....	848¼	175	12
Kalgoorlie	4,718¾	933	4	1,392½	141	10	3,524½	214	4	....	....	....	9,635¾	1,288	18
Lake Darlot	1,508¼	256	7	500	54	1	377	17	10	....	....	....	2,385¼	327	18
Leonora	506	88	6	63½	6	8	141½	7	5	....	....	....	711	101	19
Marble Bar	981½	510	3	71¾	6	19	182	12	7	....	....	....	1,235¼	529	9
Marvel Loch	1,818¼	452	16	143	15	3	1,159	89	18	....	....	....	3,120¼	557	17
Meekatharra	2,085¼	1,019	....	552½	59	13	336¼	25	16	78¾	24	....	3,052¾	1,128	9
Menzies	1,124	275	14	162¾	16	10	2,645¾	293	18	....	....	....	3,932½	586	2
Norseman	417	227	15	90	11	5	521¾	24	14	19	4	6	1,047¾	268	....
Nullagine	341	57	2	150	17	10	207¼	14	5	....	....	....	698¼	88	17
Ora Banda	2,787	770	19	436½	43	1	5,102	249	17	....	....	....	8,325½	1,063	17
Peak Hill	....	....	....	....	....	....	817	37	7	....	....	....	817	37	7
Sandstone	34¾	10	1	....	....	....	200	....	....	....	....	....	234¾	10	1
Yarri	131	24	11	142	12	13	1,850	127	4	....	....	....	2,123	164	8
Total Gold	19,200¼	5,289	13	3,985¾	412	5	20,626¼	1,317	8	132	43	10	43,944¼	7,062	16

SCHEDULE No. 4

Details of Extraction Tailings Treatment, 1963

Battery	Tons Treated	Head Value		Contents	Tail Value		Contents	Recovery	Call	Recovery	Shortage	Surplus
		Dwts.	Grs.	Dwts.	Dwts.	Grs.	Dwts.	%	£ s. d.	£ s. d.	£ s. d.	£ s. d.
Bamboo Creek	812	6	12	5,276	3	20	3,132	41	620 4 8	617 15 4	2 9 4	....
Coolgardie	2,588	2	21	7,487	....	17	1,875	75	1,192 2 0	1,172 12 11	19 9 1	....
Cue	....	....	....	....	....	....	....	....	....	8 3 8	....	8 3 8
Kalgoorlie	5,060	3	8	16,917	....	19	4,202	75	2,713 16 2	2,698 5 10	15 10 4	....
Marble Bar	2,821	8	5	23,140	5	....	14,160	39	1,907 5 0	1,959 18 3	....	52 13 3
Marvel Loch	1,734	3	21	6,747	1	4	2,088	69	989 12 10	815 10 3	174 2 7	....
Meekatharra....	1,540	3	5	4,964	1	9	2,122	57	603 11 1	329 16 9	273 14 4	....
Menzies	1,955	3	19	7,460	1	....	1,979	73	1,164 0 11	1,233 1 0	....	69 0 1
Ora Banda	1,425	3	14	5,124	....	17	1,051	79	865 1 4	392 6 11	....	27 5 7
Total	17,935	4	7	77,115	1	17	30,609	61	10,055 14 0	9,727 10 11	485 5 8	157 2 7

Net Shortage	£328 3s. 1d.
Head Value	4 dwts. 7 grains.
Tail Value	1 dwt. 17 grains.
Theoretical Recovery	60 per cent.
Actual Recovery	59 per cent.

SCHEDULE No. 5

Direct Purchase of Tailings, Year Ended 31*st December*, 1963

Battery	Tons of Tailings Purchased	Amount Paid at £4 4s. 11½d. per oz.	Amount Paid Account of Premium
Bamboo Creek	....	....	179 1 2
Boogardie	105·75	16 11 10	38 3 6
Coolgardie	1,712·00	524 19 7	1,426 4 1
Cue	13·50	2 4 9	5 2 9
Kalgoorlie	4,737·00	1,170 18 2	2,951 4 3
Lake Darlot	1,631·50	255 11 0	586 14 1
Leonora	455·25	81 9 2	186 19 9
Marble Bar	913·50	881 16 5	2,142 16 7
Marvel Loch	1,823·25	656 15 1	1,618 19 8
Meekatharra	1,773·75	616 7 6	1,503 12 6
Menzies	1,145·50	426 19 7	1,168 3 0
Norseman	396·75	528 15 2	1,213 17 3
Nullagine	348·50	48 12 2	111 11 9
Ora Banda	2,363·50	1,376 0 0	3,318 13 7
Peak Hill	16·25	2 5 3	5 3 10
Sandstone	31·25	17 4 3	39 10 4
Yarri	131·75	37 13 10	86 10 6
Total	17,599·00	6,644 3 9	16,582 8 7

SCHEDULE No. 6

Cyanide Yield, 1963

Battery	Tons	Fine oz.	Value	Premium	Total
			£	£	£
Bamboo Creek	812	143·22	617·766	1,629·461	2,247·227
Coolgardie	2,588	276·07	1,172·650	3,140·844	4,313·494
Cue	....	1·91	8·184	21·796	29·980
Kalgoorlie	5,060	630·09	2,698·291	7,168·665	9,806·956
Marble Bar	2,821	458·46	1,959·912	5,215·942	7,175·854
Marvel Loch	1,734	191·98	815·512	2,184·292	2,999·804
Meekatharra	1,540	77·64	329·839	883·445	1,213·284
Menzies	1,955	270·62	1,233·050	3,078·878	4,311·928
Ora Banda	1,425	210·06	892·345	2,389·853	3,282·198
	17,935	2,260·05	9,727·549	25,713·176	35,440·725

SCHEDULE No. 7

Statement of Receipts and Expenditure for the Year Ended 31st December, 1963

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	249	271 3 11	544 3 1	375 5 7	1,190 12 7	95 8	512 16 3	683 3 9	2,386 12 7	191 8	150 9 4	12 1	....	2,236 3 3
Coolgardie	5,528	2,820 1 10	5,071 10 7	2,800 14 9	10,692 7 2	38 11	2,665 9 7	2,471 18 0	15,829 14 9	57 3	2,221 17 2	8 1	....	13,607 17 7
Cue	872¼	3,170 6 6	2,257 13 6	982 4 11	6,410 4 11	146 11	1,782 17 10	1,997 4 5	10,190 7 2	233 8	482 13 6	11 1	....	9,707 13 8
Kalgoorlie	9,635¾	5,396 14 3	9,690 9 8	7,963 16 10	23,051 0 9	47 10	6,382 2 6	4,545 5 0	33,978 8 3	70 6	4,662 12 0	9 8	....	29,315 16 3
Lake Darlot	2,385¼	3,064 4 9	3,931 14 4	1,089 1 6	8,085 0 7	67 9	1,324 14 11	1,247 2 0	10,656 17 6	89 3	1,343 1 1	11 3	....	9,313 16 5
Laverton	....	....	138 0 0	....	138 0 0	....	34 2 10	55 17 5	228 0 3	....	120 0 8	....	....	107 19 7
Leonora	711	758 8 4	1,213 1 11	637 6 1	2,608 16 4	73 5	862 3 8	555 5 6	4,026 5 6	113 3	414 13 6	11 8	....	3,611 12 0
Marble Bar	1,311¼	2,961 19 2	1,792 16 3	1,348 3 10	6,102 19 3	93 1	1,432 2 10	1,119 5 9	8,654 7 10	132 1	999 13 8	15 3	....	7,654 14 2
Marvel Loch	3,120¼	1,983 6 9	5,671 2 0	1,635 7 6	9,289 16 3	59 7	1,468 15 7	1,438 6 7	12,196 18 5	78 2	1,713 16 6	11 0	....	10,483 1 11
Meekatharra	3,052¾	2,853 0 1	5,564 1 6	1,577 17 1	9,994 18 8	65 6	1,845 19 9	1,939 4 8	13,780 3 1	90 4	1,429 3 1	9 5	....	12,351 0 0
Menzies	3,932½	1,454 19 0	4,039 1 7	1,925 3 0	7,419 3 7	37 9	1,425 1 1	1,665 13 10	10,509 18 6	53 5	1,980 4 10	10 1	....	8,529 13 8
Norseman	1,047¾	1,645 8 1	2,444 1 11	1,047 17 0	5,137 7 0	98 1	213 0 7	1,037 9 9	6,387 17 4	121 11	702 5 11	13 5	....	5,685 11 5
Nullagine	698¼	1,110 19 3	1,606 4 4	419 6 3	3,136 9 10	89 10	549 10 3	611 19 7	4,297 19 8	123 1	423 18 10	12 2	....	3,874 0 10
Ora Banda	8,325½	2,633 10 1	5,156 19 4	2,843 12 0	10,634 1 5	25 6	1,651 10 8	3,275 9 9	15,561 1 10	37 5	2,823 0 9	6 9	....	12,738 1 1
Paynes Find	....	....	289 9 0	....	289 9 0	....	....	185 15 8	475 4 8	....	264 17 0	....	....	210 7 8
Peak Hill	817	427 7 1	1,069 10 10	216 12 11	1,713 10 10	41 11	39 8 3	296 18 0	2,049 17 1	50 2	351 15 6	8 7	....	1,698 1 7
Sandstone	234¾	213 0 0	504 13 3	276 19 4	994 12 7	84 9	495 5 5	257 12 11	1,747 10 11	148 11	127 13 11	10 11	....	1,619 17 0
Yarri	2,123	2,022 10 6	2,502 18 1	1,059 10 6	5,584 19 1	52 7	1,719 2 11	1,121 3 8	8,425 5 8	79 5	1,159 9 6	10 11	....	7,265 16 2
Head Office	....	....	....	....	....	....	....	....	....	....	17 19 5	....	17 19 5	....
Sub-Total	44,044¼	32,786 19 7	53,487 11 2	26,198 19 1	112,473 9 10	51 1	24,404 4 11	24,504 16 3	161,382 11 0	73 4	21,389 6 2	9 9	17 19 5	140,011 4 3
Northampton	4½	2,014 6 2	125 4 10	392 15 2	2,532 6 2	....	1,197 9 10	497 2 7	4,226 18 7	....	10 0 0	44 6	....	4,216 18 7
Total	44,048¾	34,801 5 9	53,612 16 0	26,591 14 3	115,005 16 0	52 3	25,601 14 9	25,001 18 10	165,609 9 7	75 2	21,399 6 2	9 9	17 19 5	144,228 2 10
Net Loss	....	....	....	....	....	....	....	....	....	....	....	....	....	144,210 3 5

SCHEDULE No. 8

Receipts and Expenditure, 1963

Cyaniding

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.
Bamboo Creek	812	148 12 0	1,380 17 9	343 19 6	1,873 9 3	46 2	....	468 9 9	2,341 19 0	57 8	66 0 0	1 8	....	2,275 19 0
Coolgardie	2,588	1,002 6 2	2,928 19 1	874 8 8	4,805 13 11	37 2	358 6 10	1,888 13 4	7,052 14 1	54 6	2,030 15 5	15 8	....	5,021 18 8
Kalgoorlie	5,060	1,994 16 5	4,414 12 5	2,765 9 9	9,174 18 7	36 3	184 8 2	3,114 7 2	12,473 13 11	49 4	7,853 3 3	31 1	....	4,620 10 8
Marble Bar	2,821	547 18 4	3,372 12 0	872 10 7	4,793 0 11	34 0	38 13 2	1,256 16 5	6,088 10 6	43 2	....	....	....	6,088 10 6
Marvel Loch	1,734	1,243 2 11	2,104 16 10	1,025 17 11	4,373 17 8	50 5	95 4 10	1,157 8 9	5,626 11 3	64 11	1,747 9 4	20 2	....	3,879 1 11
Meekatharra	1,540	497 18 6	2,536 14 8	1,867 12 11	4,902 6 1	63 8	68 1 7	854 13 9	5,825 1 5	75 8	41 13 11	6	....	5,783 7 6
Menzies	1,955	931 1 7	3,669 0 11	951 1 10	5,551 4 4	56 9	151 0 1	840 13 7	6,542 18 0	66 11	2,655 18 6	27 2	....	3,886 19 6
Ora Banda	1,425	422 14 11	1,659 2 10	528 5 8	2,610 3 5	36 8	40 16 2	562 2 4	3,213 1 11	45 1	2,047 3 1	28 9	....	1,165 18 10
Cue	....	....	....	....	....	....	....	....	....	....	28 14 0	....	28 14 0	....
Total	17,935	6,788 10 10	22,066 16 6	9,229 6 10	38,084 14 2	42 6	936 10 10	10,143 5 1	49,164 10 1	54 10	16,470 17 6	18 4	28 14 0	32,722 6 7

	£ s. d.		£ s. d.
Total Receipts	16,470 17 6		
Interest Paid to Treasury	2,160 0 0		2,160 0 0
	14,310 17 6	Gross Loss	34,882 6 7
		Less Profit	28 14 0
		Net Loss	34,853 12 7

STATE BATTERIES

Trading and Profit and Loss Account for the Year ended 31st December, 1963

1962		1963	
£		£	£
	Trading Costs—		
113,234	Wages	117,270	
40,725	Stores	35,821	
22,845	Repairs, Renewals and Battery Spares	26,538	
31,266	General Expenses and Administration	35,145	
208,070			214,774
	Earnings—		
47,878	Milling and Cyaniding Charges		35,710
160,192	Operating Loss for the Year		179,064
	Other Charges—		
26,017	Interest on Capital	26,362	
13,684	Depreciation	12,781	
2,771	Superannuation—Employers' Share	2,731	
42,472			41,874
£202,664	Total Loss for the Year		£220,938

STATE BATTERIES

Balance Sheet as at 31st December, 1963

31st December, 1962	Funds Employed	31st December, 1963	
£		£	£
	Capital—		
626,163	Provided from General Loan Fund	633,817	
137,204	Provided from Consolidated Revenue Fund	137,204	
763,367			771,021
	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—		
1,024,969	Interest on Capital		1,051,330
5,000	Advance for Purchase of Tailings		10,000
	Other Funds—		
1,691,163	Provided from Consolidated Revenue Fund (Excess of payment over collections)		1,875,182
3,526,907			3,749,941
	Deduct—		
	Profit and Loss :		
3,113,581	Loss at Commencement of year	3,316,245	
202,664	Loss for Year	220,938	
3,316,245	Total Loss from Inception		3,537,183
£210,662			£212,758
	Employment of Funds		
	Fixed Assets—		
757,776	Plant, Buildings and Equipment	765,430	
642,906	*Less* Depreciation	655,687	
114,870			109,743
	Current Assets—		
4,436	Debtors	2,210	
78,344	Stores	84,905	
2,528	Battery Spares	2,876	
	Purchase of Tailings :		
1,836	Treasury Trust Account	3,045	
52,709	Tailings not Treated	57,511	
7,183	Estimated Gold Premium	7,740	
147,036			158,287
261,906	Total Assets		268,030
	Deduct—		
	Current Liabilities :		
10,206	Creditors	9,934	
32,310	Liability to Treasurer (Superannuation—Employers' Share)	35,042	
	Purchase of Tailings :		
1,545	Creditors	2,556	
7,183	Estimated Premium Due	7,740	
51,244			55,272
£210,662			£212,758

DIVISION IV

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Annual Report of the Geological Survey Branch of the Mines Department for the year 1963

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DIVISION IV

Annual Report of the Geological Survey Branch of the Mines Department for the Year 1963

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 1963, together with some reports on investigations made for departmental purposes.

REORGANISATION

The reorganisation and enlargement of the staff, initiated in 1961, was completed by May, 1963, when the appointments to all newly created positions were completed.

With the Survey at full strength it became obvious that additional assistance would be required by the Technical Information Officer and in the clerical section. Approval was given to appoint two officers to relieve this problem.

The Hydrology and Engineering Geology Division found that it could not cope with the demands for service from other Government departments, particularly Public Works and the public. It was necessary in some instances to limit the assistance given and there was a serious lag in carrying out inspections to provide advice on the location of bore sites for landholders.

The demand from the Survey's field staff for palaeontological services increased rapidly. This applied particularly to palynological examination of samples from water bores to ascertain the geological age of strata encountered. Eventually it will be necessary to appoint a palynologist to handle this work.

STAFF

Appointments

Name	Position	Effective Date
Professional:		
J. L. Daniels, Ph.D., M.Sc.	Geologist, Grade 2	10/1/1963
E. P. D. O'Driscoll, B.E., M.Sc.	Chief Hydrogeologist	11/2/1963
B. Yonge, B.Sc. (Hons.)	Geologist, Grade 2	5/3/1963
E. E. Swarbrick, Ph.D., B.Sc. (Hons.)	Geologist, Grade 2	28/3/1963
P. Whincup, B.Sc. (Hons.)	Geologist, Grade 2	23/5/1963
Clerical and General:		
G. A. Mowbray	Typist	11/2/1963
D. H. Johnston	Clerk	18/2/1963
D. L. Bamford	Typist	22/2/1963
I. C. Dodge	Messenger	13/3/1963
A. Visschedyk	Messenger	11/9/1963
R. M. Landquist	Typist	14/10/1963
Transfers:		
D. L. Bamford	Typist	14/10/1963
Resignations:		
M. L. Cook	Typist	24/1/1963
G. A. Mowbray	Typist	14/2/1963
W. R. K. Jones	Geologist Grade 1	15/11/1963
Deceased:		
I. C. Dodge	Messenger	6/10/1963

ACCOMMODATION

The office accommodation for the Geological Survey remains unsatisfactory. The Survey is housed now in four separate buildings in two different streets, with the added disadvantage of being on the opposite side of the city to the Drafting Branch and the Head Office of the Mines Department. This results in too much time being consumed in interbuilding communications.

Once again it is urged that plans should be made now for the future housing of the Geological Survey in one building.

Plans have been drawn up for an extension to the Dianella Store to house the Survey's rock and mineral collection, which is stored temporarily at the Museum.

OPERATIONS

The majority of the projects programmed for 1963 were commenced or completed. The exceptions were the investigation by drilling of low grade manganese at Ravensthorpe, which was not done due to the decision of the Bureau of Mineral Resources at a late stage not to proceed with the project, and the investigations of the pegmatites in the Yalgoo and Murchison Goldfields was not commenced due to other commitments.

Projects not completed during 1963 have been included in the 1964 programme, which is set out later in this report.

The Geological Survey organised the Underground Water Conference when it was held in Perth for the first time from 8th to 10th May. Amongst the 32 delegates and observers who attended were representatives from all States and the Commonwealth.

The Geological Survey was represented at the South Australian Conference of the Australasian Institute of Mining and Metallurgy in August.

The Chief Hydrogeologist, Mr. E. P. O'Driscoll, attended the National Symposium on Water Resources, Use and Management conducted at Canberra by the Australian Academy of Science and presented a paper.

HYDROLOGY AND ENGINEERING GEOLOGY DIVISION

E. P. D. O'Driscoll (Chief Hydrogeologist), K. Berliat (Senior Geologist), F. R. Gordon (Senior Geologist), J. D. Wyatt, K. H. Morgan, J. R. Passmore, A. D. Allen, C. Emmenegger, E. E. Swarbrick, B. Yonge.

Hydrology

During the year, two exploratory bores were drilled along an east-west section from Byford to Kwinana, completing the project of six bores.

In the Lake Allanooka area, 11 bores were drilled by contractors under departmental direction, and the existence of a considerable reserve of good quality groundwater has been proved. This is to be developed to augment supplies for Geraldton.

Near Arrino, two completed bores were drilled and a third is under construction. These indicate that water for the Morawa district may be available from this source.

At Hyden, five bores were drilled at the request of the Department of Agriculture to investigate groundwater conditions. Prospects of obtaining even stock quality water are, in general, poor.

Valleys in the orchard district of the Karragullen-Kalamunda area were test drilled in three localities, 15 "Gemco" drilled bores and four "hammer-drill" bores being constructed. Indications are that only limited supplies of water are available.

At the request of the Metropolitan Water Supply Department, an area near Gnangara Lake on the northern outskirts of the Perth Metropolitan Area was pattern drilled with 11 bores, to test the occurrence of groundwater to augment the city supply. A substantial body of good quality water exists, and investigations are continuing.

For the Public Works Department four exploratory bores were drilled at Mandurah, one each at Capel and at Eaton, three at Watheroo, and two at Lancelin, to prove township water supplies. Bore sites were also selected and followed by drilling at Exmouth, Wyndham and Northampton for the Public Works Department and Mt. Minnie for the Department of the North-West. A total of 61 inspections followed by groundwater reports were also made for various utilities and landholders.

An assessment of groundwater resources was also made in conjunction with regional mapping in the East Kimberley area.

Two lectures were delivered to groups of interested landholders.

A two-year research project at Rockingham was approved by the Water Research Foundation, and became the subject of a special research grant to an officer seconded from the Division for 1964-65.

Engineering Geology

The main work of this section was the investigation of dam sites and of the Avon Valley Deviation of the Standard Gauge Railway.

Reconnaissance mapping, trenching, auger and diamond drilling and water pressure tests were included in the work on dam sites for the Metropolitan Water Supply Department at Goorolong Brook near Jarrahdale, South Canning River, Upper Wungong and Lower Wungong, all in the Darling Range.

Work continued on the Ord River Main Dam Site in the Kimberleys for the Public Works Department and a reconnaissance was made of the dimension stone resources and the general geology of the Secure Bay-Walcott Inlet area, for a proposed tidal power station.

The proposed Waroona Dam was resited on geological advice. Inspections were made and reports submitted on two harbour works areas, Geraldton and Broome, and several quarry sites.

The Standard Gauge Railway deviation project was examined in detail between Perth and Southern Cross, the work covering sources of materials, foundation and excavation conditions, batters for rock cuttings, and preventive and remedial measures during construction.

SEDIMENTARY (OIL) DIVISION

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

Field work was conducted during the year in the Canning and Perth Basins. In the Canning Basin the detailed mapping of the Devonian reef complexes of the Lennard Shelf, begun in 1962, was continued. This project will be completed during 1964. In the Perth Basin regional mapping and collection of hydrological data in the Busselton—Margaret River—Capel area was continued, and further work was carried out in the Pinjarra—Rockingham and Gingin—Dandaragan areas. It is expected that mapping of the southern half of the basin will be completed during 1964.

A project designated to appraise the glauconite reserves of the Gingin—Dandaragan area was initiated, and the first of 13 programmed drill holes (using Gemco equipment) was completed near Dandaragan. This project will be continued in 1964.

The progress of oil exploration in Western Australia was followed closely during the year, and the work programmes of oil exploration companies were reviewed.

The Supervising Geologist visited Bureau of Mineral Resources parties operating in the Amadeus Basin for approximately two weeks during May and June.

REGIONAL GEOLOGY DIVISION

R. C. Horwitz (Supervising Geologist), J. Sofoulis (Senior Geologist), G. R. Ryan, M. J. B. Kriewaldt, I. Gemuts.

Eastern Goldfields Area

Field work was completed on the Widgiemooltha 1:250,000 Sheet. Information was supplied on hydrological and mineral resources problems in the area, and reports were written on groundwater investigations for pastoralists in the Bullfinch, Menzies, Wilson's Patch and Coonana areas.

West Pilbara Goldfield

Field work was completed on the Roebourne and Pyramid 1:250,000 Sheets. Information was supplied to residents and mining companies on hydrological, mineral resources and general geology problems in the area.

East Kimberley Area

The joint regional mapping programme with the Bureau of Mineral Resources was continued. Field work was completed on the Dixon Range, Lissadell and Cambridge Gulf 1:250,000 Sheets.

Perth Basin

In conjunction with the Sedimentary Division, mapping of the Precambrian geology on the Busselton and Augusta 1:250,000 Sheets was completed and mapping on the Perth 1:250,000 Sheet was commenced.

MINERAL RESOURCES DIVISION

W. N. MacLeod (Supervising Geologist), L. E. de la Hunty (Senior Geologist), W. R. K. Jones, R. Halligan, J. L. Daniels.

The main operation undertaken by the Division in 1963 was the completion of the regional survey of the Hamersley Iron Province. This mineral province has now been mapped on a scale of 1:250,000 with selected areas of economic importance mapped in greater detail. Most of the significant iron deposits in this region have been examined. During the year particular attention was paid to the hematite deposits near Weeli Wolli Spring and in the Mt. Newman area of the Ophthalmia Range.

The Roy Hill, Newman and Turee Creek 1:250,000 Sheets were completed during the field season and some work was done on the adjoining Wyloo and Robertson Sheets. The regional survey of the iron province was extended to cover mineralised areas in the Ashburton Valley and liaison was maintained with exploration companies working there. All staff of the Division were engaged on the iron survey for varying periods throughout the year. The Mt. Bruce Sheet, mapped during the 1962 field season, is being prepared for publication.

The Supervising Geologist examined and reported upon the Pompey's Pillar iron deposits in the Kimberley Division, the Mt. Gibson iron deposits in the Yalgoo Goldfield, and deposits of beneficiable iron ore in the Koolanooka and Yalgoo areas.

Examinations were made of bauxite deposits near Boddington and Jarrahdale, mineral sand deposits along the scarp of the Darling Range near Mundijong, and a mica deposit near Mullalyup.

COMMON SERVICES DIVISION

Petrology (A. F. Trendall)

During the first full year of operation, 32 file reports were written describing rock collections containing between one and 96 specimens. These were received mainly from the Regional Geology and Mineral Resources Divisions but some work was also done for the Hydrology and Sedimentary Divisions, for the public and for other Government departments. The great majority of rocks examined were from the Pilbara area.

The only special study initiated during the year was on aspects of lateral variation in some Precambrian iron formations, but other problems on which particular attention continued to be focussed include porphyries, particularly in their relationship to sediments of the same age, basalts from the Perth Basin, and acid volcanic rocks from the Pilbara area.

A total of 1,096 thin sections were prepared in the laboratory. Petrographic techniques available are limited to the examination of thin and polished sections with a petrological microscope equipped with a wide range of accessories, coupled with limited physical and chemical apparatus. Quantitative chemical analyses and X-ray diffraction determinations of minerals were carried out by the Government Chemical Laboratories, from whom much assistance during the year is gratefully acknowledged.

Palaeontology (H. S. Edgell)

During 1963 requests for palaeontological examination of many types of material were handled, and 72 file reports and five records were written.

The principal emphasis of palaeontological work was in the field of palynology. This study of fossil spores, pollen grains and microplankton provided basic information on the geological age, facies and formation of strata encountered in some 60 bore sequences examined. Most of this information was requested by the Hydrology Division, as a stratigraphic background to underground water investigations, particularly in the Mandurah, Gnangara Lake and Wicherina—Allanooka areas. Many surface samples from the southern part of the Perth Basin were determined palynologically for detailed mapping by the Sedimentary Division and for studies of the hydrogeology of the basin. Predominance of non-marine or paralic sediments in the Perth Basin makes palynology the most useful method of determining their age and formation since the conventional, marine microfossils are rarely encountered.

In connection with the exploration for oil in this State, micropalaeontological studies were done for West Australian Petroleum Pty. Ltd., on the age and correlation of sampled sequences from their Marrilla No. 1 and Minderoo No. 1 Wells. Subsurface samples from Whaleback No. 1 Well and additional surface samples from Barrow Island were also examined. Micropalaeontological age determinations were made of Cretaceous strata from a United Geophysical shothole at Mindarra and from the G.S.W.A. Lancelin No. 1 Water Bore.

Megafossil material examined included stromatoporoid and algal collections from the Devonian reef-complexes of the Lennard Shelf to assist studies being made by the Sedimentary Division. Additional collections were made, particularly of oriented stromatoporoid colonies, during a visit to the area. Among the megafossils examined was a group of ammonite impressions found by Dr. P. E. Playford in the Northampton district. Pleistocene molluscan assemblages were also studied from ferruginized terrace deposits in the vicinity of Busselton.

Considerable advances were made during the year in the application of palaeontology to the Precambrian sediments of Western Australia. At least three distinctive assemblages of calcareous algae of the stromatolite type were recognised in the Proterozoic sequences of the North-West Division and Kimberley Division. These algal "horizons" have proved useful both for local mapping and regional correlation. Extensive collections of stromatolites were made during a visit to the West Pilbara area. Medusoid impressions and microfossils were also identified from the jaspilites of the Brockman Iron Formation.

Geophysics (D. L. Rowston)

Geophysical investigations carried out during 1963 were again mainly related to hydrological and engineering geological projects. The latter included seismic refraction surveys using the seismic timer equipment at the Wungong Brook upper and lower dam sites, the Gooralong dam site and the proposed new Meckering Railway Station. Experimental resistivity, self potential and seismic work were continued in the Karragullen—Kalamunda area in conjunction with hydrological research. Some determinations of the depth to granite, using the seismic timer equipment, were made to assist in bore site selection in this area.

A Widco Well-logger was received and put into operation. The well-logger is capable of recording continuously, variations in electrical resistivity, self potential, gamma radiation and temperature in bores drilled to depths of 2,500 feet. Several exploratory water bores at Mandurah were logged.

At the request of West Australia Petroleum Pty. Ltd. a ground magnetometer survey was made over the Gogo Structure south of Fitzroy Crossing to determine the depth to magnetic basement. The magnetic results substantiated the seismic interpretation of the thickness of sediments.

A seismograph station using a vertical component Willmore Seismograph unit to detect near-earthquake activity was installed at Kununurra for the Department of Works. The University of W.A. were assisted in the design of electromagnetic prospecting equipment, and laboratory investigations commenced on a down-hole conductivity and temperature measuring device for the Hyrodology Division.

Technical Information Officer (R. R. Connolly)

In the library, general services were maintained and the index to economic minerals referred to in departmental publications, was brought up to date by the Library Assistant. The aerial photograph library was re-organised and normal expansion of this unit continued.

A number of publications, mainly Explanatory Notes Series, were prepared for printing and 38 Records were issued. The indexing of plans and maps was continued during the year, and work began on the indexing and systematic storage of special confidential technical reports submitted under the requirements of exploration permits.

Several mineral displays were organised, one at the Royal Agricultural Show depicting the relationship of industry to mining development in this State.

In the core library at Dianella, core and sludge storage racks were re-designed for better space utilisation. Extensions to the core library were planned and designed to provide office facilities and storage for the registered rock collection.

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

ACTIVITIES OF THE COMMONWEALTH BUREAU OF MINERAL RESOURCES

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

(1) Regional mapping of the Dixon Range, Lissadell, Cambridge Gulf and Medusa Banks 1:250,000 Sheets in the East Kimberley area, jointly with the Geological Survey of Western Australia.

(2) Sampling of suitable Precambrian rocks in the East Kimberley area for age determination studies.

(3) A regional seismic line across the southern part of the Carnarvon Basin and the northern part of the Perth Basin.

PROGRAMME FOR 1964

HYDROLOGY AND ENGINEERING GEOLOGY DIVISION

Hydrology

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

(ii) Hydrological investigation and/or exploratory drilling for underground water supplies in the following areas: Allanooka (Geraldton town water supply), Mandurah, Wicherina, Lake Gnangara, Arrowsmith River (Morawa town water supply), Hyden, Gingin, Dongara, Muja, Albany, Bremer Bay, Donnybrook, Esperance and Midlands Light Land (West Dandaragan).

(iii) Hydrological investigation of the "Hills" fruit growing area.

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

(a) Bore site selection as required by pastoralists.

(b) Regional mapping in conjunction with the Bureau of Mineral Resources.

(v) Investigation of requests for assistance in bore site selection by pastoralists in the Eastern Goldfields area.

(vi) Miscellaneous minor investigations as required.

Engineering Geology

(i) Supervision of drilling, inspection of shafts and mapping at Ord River Main Dam Site.

(ii) Supervision of drilling at Gogo Barrage.

(iii) Standard Gauge Railway:

(a) Completion of Avon Valley Deviation.

(b) Reassessment of Merredin—Southern Cross Section.

(iv) Investigation of dam sites for Metropolitan Water Supply Department: South Canning, Wungong Brook, Gooralong Brook (Jarrahdale), and Dandalup Brook (two sites).

(v) Investigation of dam sites for Public Works Department: Waroona Dam, Harvey Dam, Harris River, Gascoyne River (three sites), and Denmark River.

(vi) Investigations for the tidal power scheme in the Secure Bay area.

(vii) Miscellaneous minor investigations as required.

SEDIMENTARY (OIL) DIVISION

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

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

(iii) Continuation and completion of the geological survey of the Lennard Shelf area, Canning Basin.

(iv) An appraisal of the Lower Jurassic coal deposits of the Perth Basin.

(v) Continuation and completion of glauconite investigations in the Gingin—Dandaragan area.

(vi) Miscellaneous investigations as required.

REGIONAL GEOLOGY DIVISION

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

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

(iii) Continuation of regional mapping, in conjunction with the Bureau of Mineral Resources, on the Mt. Ramsay, Lansdowne and Lennard River 1:250,000 Sheets in the Kimberley area.

MINERAL RESOURCES DIVISION

(i) Continuation of regional mapping and mineral investigations in the Ashburton area.

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

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

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

(v) Investigation of vermiculite deposits at Young River.

(vi) Miscellaneous minor investigations as required.

PUBLICATIONS AND RECORDS

During 1963, three bulletins were printed and issued. This has cleared the back lag of bulletins awaiting publication.

Thirty-eight Records were prepared during the year while a number of 1:250,000 geological maps with explanatory notes are in the course of preparation.

Issued During 1963

Annual Progress Report for 1961.

Bulletin No. 115, The Geology of Portion of the Pilbara Goldfield covering the Marble Bar and Nullagine 4 mile Map Sheets, by A. J. Noldart and J. D. Wyatt.

Bulletin No. 116, The Geology of the Manganese Deposits of Western Australia, by L. E. de la Hunty.

Mineral Resources Bulletin No. 8, Copper Deposits of Western Australia, by G. H. Low.

In Press

Annual Report for 1962.

Geological Map of Boorabbin 1:250,000 Sheet (SH51-13 International Grid) with Explanatory Notes.

Geological Map of Balfour Downs 1:250,000 Sheet (SF51-9 International Grid) with Explanatory Notes.

In Preparation

The following 1:250,000 Geological Maps with Explanatory Notes are in the course of preparation: Dampier and Barrow Island, Port Hedland, Mt. Bruce, Roy Hill, Newman, Roebourne, Pyramid, Turee Creek, Widgiemooltha, Augusta and Busselton.

Bulletin—The Hamersley Iron Province.

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

Records Produced

Number	Author(s)	Title
1963/1	Emmenegger, C.	Report on Laporte No. 5 Water Bore Australind, W.A. (*Restricted*).
1963/2	Gordon, F. R.	W.A.G.R. Standard Gauge Railway, Kalgoorlie to Kwinana : Geological Reconnaissance, Northam to Kellerberrin.
1963/3	Emmenegger, C.	Report on Eaton No. 1 Bore.
1963/4	Gordon, F. R.	Jarrahdale Dam Site—Diamond Drilling Programme.
1963/5	Gordon, F. R.	The Avon Valley Deviation, W.A.G.R. Standard Gauge Railway.
1963/6	Gordon, F. R.	Rock Stability, Second Rock Cutting, Avon Valley Deviation, W.A.G.R.
1963/7	Gordon, F. R.	Windmill Hill Cutting—Rock Stability, Avon Valley Deviation of the Standard Gauge Railway.
1963/8	Gordon, F. R.	Engineering Geology of the Ord River Main Dam Site No. 2.
1963/9	Gordon, F. R.	Rock Cutting at West Toodyay, W.A.G.R. Avon Valley Deviation, Standard Gauge Railway.
1963/10	Wyatt, J. D.	A Preliminary Investigation of the Proposed Fitzroy River Barrage Site.
1963/11	MacLeod, W. N., de la Hunty, L. E. Jones, W. R. K., Halligan, R.	A Preliminary Report on the Hamersley Iron Province, North-West Division
1963/12	Morgan, K. H.	Hydrology of the Gordon Downs 1 : 250,000 Sheet, Kimberley Division, Western Australia.
1963/13	Passmore, J. R.	Report on the Groundwater of the Bridgetown Area.
1963/14	MacLeod, W. N.	The Iron Deposits near Pompey's Pillar, Kimberley Division. (*Restricted*.)
1963/15	Emmenegger, C.	Report on Capel Town Bore No. 1.
1963/16	Rowston, D. L.	Wungong Brook Upper Dam Site—Geophysical Investigations.
1963/17	Berliat, K.	Report on Exploratory Drilling for Groundwater in the Sandplain Country 40 Miles East of Hyden.
1963/18	Gordon, F. R.	Windmill Hill Cutting—Rockslide—Standard Gauge Railway—Avon Valley Deviation.
1963/19	Low, G. H.	Explanatory Notes on the Port Hedland 1 : 250,000 Geological Sheet.
1963/20	Lord, J. H.	The Woolgorong Stony Meteorite.
1963/21	Edgell, H. S.	Micropalaeontology and Stratigraphy of Marrilla No. 1 Bore, Carnarvon Basin, W.A. (*Restricted*.)
1963/22	Gordon, F. R.	Horseshoe Hill Rock Excavation, W.A.G.R. Standard Gauge Railway—Avon Valley Deviation.
1963/23	Edgell, H. S.	Micropalaeontology and Stratigraphy of Minderoo No. 1 Bore, Carnarvon Basin, W.A. (*Restricted*.)

Records Produced—continued

Number	Author(s)	Title
1963/24	Kriewaldt, M. J. B.	Explanatory Notes on the Dampier 1 : 250,000 Geological Sheet, Western Australia.
1963/25	Gordon, F. R.	Ord River Main Dam Site No. 2—Design Conference.
1963/26	MacLeod, W. N.	Iron Ore Deposits Near Mount Gibson, Yalgoo Goldfield. (*Restricted.*)
1963/27	Gordon, F. R.	Engineering Geology of the Waroona Dam Site. Preliminary Appraisal.
1963/28	Gemuts, I.	Preliminary Report on the Copper Mineralization in the Duffers Limestone, near Hall's Creek, Kimberley Goldfield. (*Confidential.*)
1963/29	Sofoulis, J.	Report on a New Goldfield North-East of Karonie, Kurnalpi District, N.E. Coolgardie Goldfield. (*Restricted.*)
1963/30	Swarbrick E. E.	Report on Groundwater Prospects, Northampton Townsite.
1963/31	Emmenegger, C.	Report on G.S.W.A. Mandurah No. 2 Water Bore, Mandurah, W.A.
1963/32	Ryan, G. R.	Report on an Inspection of Whim Creek Copper Mine, West Pilbara Goldfield, W.A. (*Confidential.*)
1963/33	Berliat, K.	Report on Exploratory Drilling for Underground Water in the Perth Basin West of Byford, W.A.
1963/34	Edgell, H. S.	The Occurrence of Upper Cretaceous Marine Strata of Campanian Age at Lancelin, Perth Basin.
1963/35	Gordon, F. R.	Report on No. 1 Rockcut, Avon Valley Deviation, Standard Gauge Railway.
1963/36	MacLeod, W. N.	An Outline of the Result of Iron Ore Exploration in W.A. during 1963. (*Confidential.*)
1963/37	Playford, P. E., Lowry, D. C.	Wells Drilled for Petroleum Exploration in Western Australia to the end of 1963.
1963/38	Swarbrick, E. E.	Exploratory Drilling for Water, Town Supply, Northampton.

J. H. LORD,
Director.

13th March, 1964.

REPORT ON EXPLORATORY DRILLING FOR UNDERGROUND WATER IN THE PERTH BASIN, WEST OF BYFORD

By K. Berliat

ABSTRACT

Six exploratory water bores, 600 feet to 870 feet deep, were drilled across the Perth Basin, some 20 miles south of Perth.

Sediments, ranging in age from Lower Jurassic to Recent, were penetrated and correlation shows that they have a slight regional dip to the west. A major fault is postulated 3½ miles west of the Darling Fault.

Aquifers of Lower Jurassic, Lower Cretaceous and Quaternary (Pleistocene to Recent) age, were encountered. The latter two aquifers occur to the west of the abovementioned fault and are correlated across the basin. Both aquifers have hydraulic gradients to the west, indicating a general movement of underground water in that direction.

The Lower Jurassic aquifer is limited to the area between the Darling Fault and the fault 3½ miles further west. It has no hydraulic connection with any of the aquifers located further to the west. The aquifer is capable of yielding limited amounts of pressure water and recharge is effected by seepage along the Darling Fault.

The Lower Cretaceous aquifer is confined and yields large supplies of generally good quality artesian or sub-artesian water. There is a marked increase in salinity from east to west and from top to bottom of the aquifer. The intake area is adjacent to and west of the fault zone, 3½ miles west of the Darling Fault.

The shallow Quaternary aquifer is unconfined and recharged by direct infiltration of precipitation. Supplies are insignificant, except in the westernmost part of the drilling area.

INTRODUCTION

The exploratory water drilling programme discussed in this report was carried out by the Mines Department between September, 1961, and May, 1963. It consisted of six bores, totalling 4,446 feet, individual bores ranging in depth from 600 feet to 870 feet.

The drilling area (Plate 1) lies approximately 20 miles south of Perth, the bores extending along an east-west line between the townships of Byford and Medina-Calista, a distance of 12 miles. The easternmost and westernmost bores are within the townsite boundaries of Byford and Calista respectively, while the others adjoin the Armadale-Rockingham Road, or are close to it. The distance between individual bores varies from 2 to 3½ miles.

The aim of the project was to investigate the hydrogeological conditions across the Perth Basin to a depth of 800 feet. This involved, in the first instance, the elucidation of the stratigraphy and the interpretation of the geological structure. On the hydrological side it entailed the correlation of aquifers, the determination of their hydrological gradients and intake areas, the definition of salinity patterns, and pump testing to ascertain yields.

Four of the exploratory bores are either producing or have been left cased and capped, ready for future equipping. The other two have been backfilled because of insufficient supplies or lack of demand.

Palynological examinations of lithologically-suitable sludge samples, were made by Dr. H. S. Edgell, Palaeontologist of the Geological Survey of Western Australia and Mr. B. E. Balme, Senior Lecturer at the University of Western Australia, whose work is gratefully acknowledged.

Sample logs and drilling details of the six exploratory bores are given in Berliat, 1963.

DRILLING RESULTS

G.S.W.A. BYFORD No. 1 BORE

Summary Log

From	To	Thickness	Remarks	Description
feet	feet	feet		
0	99	99	....	SAND, CLAY, interbedded.
99	837	738	....	CLAYSTONE, partly carbonaceous, micaceous, with frequent fragments of coal and abundant quartz grains; includes a few thin beds of fine grained sandstone, grey, brown or black.
837	858	21	Aquifer	SANDSTONE, medium to coarse grained, quartz, grey.
858	870	12	....	CLAYSTONE, carbonaceous, with fragments of coal.

Hydrological Data

Developed aquifer zone: 837 ft.-858 ft.

Static level: 112 ft.

Yield: 8,000 gals. per hour.

Quality of water after development: 1,044 p.p.m. total dissolved solids.

Status: Capped, ready for equipping.

G.S.W.A. BYFORD No. 2 BORE

Summary Log

From	To	Thickness	Remarks	Description
feet	feet	feet		
0	32	32	....	CLAY, silty or sandy, brown.
32	46	14	Aquifer	SANDSTONE, medium to coarse, grey.
46	50	4	Aquifer	SANDSTONE, fine grained, clayey, grey.
50	82	32	Aquifer	SANDSTONE, medium to coarse grained, brown.
82	121	39	....	CLAYSTONE, SILTSTONE, grey or light brown, with pebbles of granite and quartzite.
121	170	49	Aquifer	SANDSTONE, very coarse grained, with pebbles of granite and quartzite.
170	543	373	....	CLAYSTONE, SILTSTONE, interbedded, with pebbles and cobbles of granite, quartzite and basic igneous rocks.
543	600	57	....	CLAYSTONE, carbonaceous, with fragments of coal.

Hydrological Data

Developed aquifer zone: 121 ft.-170 ft.

Static level: 16 ft. above ground level.

Yield: 7,200 gal. p.h.

Quality of water after development: 710 p.p.m. total dissolved solids.

Status: Bore head fitted with valve; in use.

G.S.W.A. BYFORD No. 3 BORE

Summary Log

From	To	Thick-ness	Remarks	Description
feet	feet	feet		
0	87	87	Aquifer	SAND, fine to medium grained, clayey.
87	232	145	....	CLAYSTONE, partly carbonaceous, with some interbedded horizons of fine grained, clayey, sandstone.
232	297	65	Aquifer	SANDSTONE, fine grained, clayey.
297	499	202	....	SILTSTONE, CLAYSTONE, interbedded, carbonaceous, calcareous, grey, greenish-grey or black.
499	700	201	....	CLAYSTONE, partly carbonaceous or calcareous, dark grey, dark brown, or black.

Hydrological Data

No development was warranted. The supplies from both aquifers were insignificant (50-150 gallons per hour) and salinities were rather high (1,400 to 2,300 p.p.m. total dissolved solids).

Status: Abandoned; bore backfilled from 700 ft. to surface.

G.S.W.A. BYFORD No. 4 BORE

Summary Log

From	To	Thick-ness	Remarks	Description
feet	feet	feet		
0	95	95	Aquifer	SAND, medium to fine grained, grey or brown.
95	132	37	Aquifer	SANDSTONE, calcareous, with shell fragments.
132	325	193	....	CLAYSTONE, carbonaceous, pyritic micaceous, black.
325	430	105	Aquifer	SANDSTONE, coarse grained, grey.
430	457	27	....	SILTSTONE, clayey, carbonaceous, dark grey.
457	632	175	Aquifer	SANDSTONE, fine to coarse grained, pyritic, micaceous, partly calcareous, greenish grey.
632	800	168	....	CLAYSTONE, carbonaceous, micaceous, dark grey to black.

Hydrological Data

Developed aquifer zone: 325 ft.-430 ft.

Static level: 70 ft.

Yield: 20,000 gal. p.h.

Quality of water after development: 300 p.p.m. total dissolved solids.

Status: Capped, ready for equipping.

G.S.W.A. BYFORD No. 5 BORE

Summary Log

From	To	Thick-ness	Remarks	Description
feet	feet	feet		
0	81	81	Aquifer	SAND, fine to medium grained, brown.
81	123	42	Aquifer	LIMESTONE, sandy, grey.
123	474	351	....	CLAYSTONE, silty, carbonaceous, micaceous, pyritic, black, grey, or brown.
474	528	54	Aquifer	SANDSTONE, medium to coarse grained, grey or brown.
528	623	95	....	SILTSTONE, clayey, micaceous, greenish-grey.
623	785	162	Aquifer	SANDSTONE, medium to coarse grained, greenish-grey or light brown.
785	800	15	....	CLAYSTONE, carbonaceous, dark grey.

Hydrological Data

Developed aquifer zone: 474 ft-528 ft.

Static level: 52 ft.

Yield: 21,000 gal. p.h.

Quality of water after development: 1,080 p.p.m. T.D.S.

Status: Capped, ready for equipping.

G.S.W.A. BYFORD No. 6 BORE

Summary Log

From	To	Thick-ness	Remarks	Description
feet	feet	feet		
0	37	37	Aquifer	SAND, medium grained, calcareous.
37	65	28	Aquifer	LIMESTONE, sandy, with shell fragments.
65	156	91	Aquifer	SANDSTONE, fine to coarse grained, brown or grey.
156	490	334	....	CLAYSTONE, carbonaceous, micaceous, pyritic, dark grey to black.
490	520	30	Aquifer	SANDSTONE, medium to coarse grained, brown.
520	542	22	....	SILTSTONE, clayey, carbonaceous, micaceous, dark grey.
542	676	134	Aquifer	SANDSTONE, medium to coarse grained, grey or brown.

Hydrological Data

Bore not developed for use because of lack of demand.

The shallow aquifer interval between 22 ft. and 156 ft. was pump tested at a rate of 32,000 gal. p.h. The salinity of the water was 460 p.p.m. T.D.S. at 65 ft. and 560 p.p.m. T.D.S. at 156 ft. The aquifers below 490 ft. are also high yielding, but salinities vary from 1,940 p.p.m. T.D.S. at 520 ft. to 2,700 p.p.m. T.D.S. at 670 ft.

Status: Abandoned; bore backfilled from 676 ft. to surface.

GEOLOGY

General

The Perth Basin is a sedimentary structure approximately 600 miles long and with a maximum width of about 60 miles, extending from latitude 26° S. to latitude 34° S. The drilling area is in the southern part of the Basin, where, in the vicinity of Byford, it has a width of 15 miles (Plate 1).

The eastern margin of the Perth Basin is defined by the Darling Fault, separating the sediments from Precambrian igneous and metamorphic rocks of the West Australian Shield.

Gravity surveys indicate a maximum total thickness of sediments in the order of 25,000 to 35,000 feet, including rocks of Proterozoic, Palaeozoic, Mesozoic, Tertiary and Quaternary ages, known either from outcrops or from bore holes.

In the Perth Metropolitan Area the following formations are known:—

Quaternary:	Coastal Limestone
	Guildford Clay
Tertiary:	King's Park Shale
Cretaceous:	Osborne Formation
	South Perth Formation
Jurassic:	Claremont Sandstone

In the drilling area the only sediments exposed are of Proterozoic and Quaternary age, i.e., the Cardup Shale and the Coastal Limestone (or aeolianites) respectively.

Exposures of Cardup Shale, a sequence of shales, slates and quartzites intruded by dolerite dykes, occur along the Darling Fault, immediately east of Byford and half a mile east of G.S.W.A. Byford No. 1 Bore (Plate 1). The formation unconformably overlies Precambrian gneisses and dips steeply to the west. Between Byford and the coast the pre-Quaternary sediments are obscured by sands, aeolianites and Coastal Limestone.

Seismic reflection results (Moss, 1962) indicate a sub-horizontal attitude of the upper part of the sediments, to a depth of approximately 1,000 feet.

STRATIGRAPHY AND CORRELATION

The Byford exploratory bores penetrated sediments of Lower Jurassic, Lower Cretaceous, Upper Cretaceous and Quaternary (Pleistocene to Recent) age. The Mesozoic sediments are marine neritic to paralic and non-marine sandstones, siltstones, mudstones and limestones. Close lithological correlations between individual bores are not possible because of lateral facies variations and the absence of distinctive marker horizons.

Sediments of Lower Jurassic age were encountered in No. 1 Bore between 135 feet and 870 feet (no diagnostic microfloral assemblages were found above 135 feet) and in No. 2 Bore between 543 feet and 600 feet. The sequence consists almost exclusively of dark grey, brown, or black, carbonaceous mudstones, with pockets, seams and laminae of coaly material and frequent inclusions of rounded quartz grains. Subordinate, interbedded horizons of siltstone or sandstone 1 to 20 feet thick were found in No. 1 Bore.

Palynology indicates a correlation of the succession with the upper part of the Cockleshell Gully Sandstone ("Coal Measures Member" in Eneabba No. 1 Well, West Australian Petroleum Pty. Ltd.) in the central Perth Basin, and with the Woodleigh Beds in the Carnarvon Basin. It is worthy of note that this is the first instance where these equivalents were established in the southern part of the Perth Basin.

In No. 2 Bore the Cockleshell Gully Sandstone equivalent is in faulted contact with the overlying Lower Cretaceous (Upper Neocomian to Aptian) strata, which, on palynological evidence, are correlated with the South Perth Formation known from artesian bores in the Metropolitan Area. This latter unit is developed as an alternating sequence of dark grey, carbonaceous, micaceous or pyritic mudstones, siltstones and sandstones, deposited in a paralic environment, with marine and non-marine facies interfingering. In No. 2 Bore the formation is characterised by a large amount of rounded pebbles and cobbles of quartzite, granite and basic igneous rocks.

In No. 3 and No. 4 Bores the entire section below the Quaternary beds is made up of the South Perth Formation, while in No. 5 and No. 6 Bores this formation was encountered below approximately 250 feet. In these two westernmost bores the South Perth Formation is unconformably overlain by the marine beds of the Osborne Formation, also known from deeper bores in the Metropolitan Area, where they are characterised by a high glauconitic content.

In the Byford bores the Osborne Formation is not glauconitic and is lithologically indistinguishable from the South Perth Formation. It ranges in age from Albian to Cenomanian.

The superficial Quaternary deposits are Coastal Limestone, aeolianites and residual sands. They reach a maximum thickness of 156 feet.

The stratigraphic correlations are shown on Plate 2.

STRUCTURE

A suggested geological cross-section across the Perth Basin west of Byford, is shown on Plate 3. The section has been prolonged beyond No. 6 Bore by incorporating subsurface information from a bore on Garden Island. This bore, 1,200 feet deep, is located in the southern part of the island 7 miles west from Byford No. 6. Consideration has also been given to the stratigraphy of a deep (2,650 feet) bore at Jandakot (Wool Scouring Works), 7½ miles north of Byford No. 5.

The following comments are offered:—

Evidence of faulting in No. 2 Bore is threefold:—

(i) Stratigraphical: Lower Jurassic sediments (Cockleshell Gully Sandstone equivalent) are in contact with late Neocomian-Aptian sediments (South Perth Formation). The Upper Jurassic Claremont Sandstone is absent.

(ii) Geophysical: A seismic traverse 5 miles south of, and roughly parallel to the line of the Byford bores (Moss 1962) indicated faulting 2½ miles west of Mundijong. If this fault is prolonged to the north, parallel to the Darling Fault, it passes through the site of Byford No. 2 Bore.

(iii) Physiographical: Water courses running off the Darling scarp either disappear (e.g. Neerigan Brook, Beenyup Brook, Cardup Brook) or are sharply deflected to the north (Wungong Brook) along a line coinciding with the postulated fault. It is considered that the disappearance of the creeks is caused by the higher permeability of the Cretaceous sediments west of the fault. The country between the fault and the Darling scarp is thought to be underlain by impervious Lower Jurassic claystones.

The fault shown close to No. 4 Bore is indicated by the seismic work mentioned above. Only horizons below approximately 1,000 feet are affected by this fault, and it has apparently been inactive during the deposition of the uppermost sediments.

In the Jandakot bore the Claremont Sandstone was encountered at approximately 2,450 feet below sea level. The relatively shallow depth of this formation (1,135 feet below sea level) in the Garden Island bore, may be explained either by a regional dip to the east, amounting to about 1½ degrees, or by faulting.

The great thickness (2,000 feet) of the South Perth Formation in the Jandakot bore, compared with less than 400 feet in the Garden Island bore, may indicate a deepening of the Perth Basin towards its central part.

The correlation of the Lower Cretaceous aquifers in the Byford bores, indicates that the strata, at least to a depth of 800 feet, have a slight dip to the west. On the other hand, seismic reflection traverses (Moss, 1962) indicated easterly dips below a depth of approximately 1,000 feet. This suggests a possible unconformity within the succession of the South Perth Formation.

The Osborne Formation was deposited on the eroded surface of the South Perth Formation and has a westerly dip. The King's Park Shale lies on an erosion surface of the Osborne Formation. The marine transgressions depositing both units have not reached the eastern areas of the Perth Basin.

HYDROLOGY

AQUIFERS

Underground water occurs in formations of Lower Jurassic, Lower Cretaceous and Quaternary age.

Lower Jurassic Aquifer

In dealing with the various aquifer systems, No. 1 Bore has to be considered separately. The aquifer encountered between 837 feet and 858 feet is of Lower Jurassic age and consists of medium to coarse grained quartz sandstone. The aquifer has no hydraulic connection with any of the aquifers intersected in the other bores, and its lateral extent is limited to the area between the Darling Fault and the fault passing through No. 2 Bore (Plate 4A).

Lower Cretaceous Aquifer

A confined aquifer of this age was encountered in all bores except No. 1, at depths ranging from 32 feet below surface in No. 2 Bore to 490 feet below surface in No. 6 Bore. The aquifer consists of fine to coarse grained sandstones interbedded with siltstones and silty mudstones. In No. 3 Bore it has very low permeability as it consists predominantly of clayey sandstone alternating with silty mudstones.

The correlation of this aquifer is based on broad lithological units and not on distinctive marker horizons or palynological data. In spite of considerable horizontal and vertical permeability variations, the different beds within the aquifer are well defined and are considered to form one hydraulically interconnected system.

Data concerning the aquifer are given in Table 1.

TABLE 1. LOWER CRETACEOUS AQUIFER.

No. of Bore	2	3	4	5	6
	ft.	ft.	ft.	ft.	ft.
R.L. of Bore Head	68	77	91	71	25
Depth to Aquifer	32	232	325	474	490
Thickness of Aquifer Zone	138	267	307	311	Not penetrated (at least 186 ft.)
R.L. of Hydraulic Surface	84	34	21	19	12

Quaternary Aquifer

Details of the shallow, unconfined aquifer, located in all bores west of No. 2 are given in Table 2. Lithologically this aquifer consists of unconsolidated, superficial sands, aeolianites, and Coastal Limestone. It is separated from the Lower Cretaceous aquifer system by a mudstone aquiclude, varying in thickness from 154 feet to 351 feet.

TABLE 2. QUATERNARY AQUIFER

No. of Bore	3	4	5	6
	ft.	ft.	ft.	ft.
R.L. of Bore Head	77	91	71	25
Depth to Water Table	5	31	40	22
Thickness of Aquifer	82	101	83	134
R.L. of Water Table	72	60	31	3

Aquifer correlations are shown in Plate 4A.

YIELD

The yield of the aquifers is indicated by pump tests, the results of which are shown in Table 4.

With the exception of No. 6 Bore, no pump tests were carried out for the Quaternary aquifer. Bailing in No. 3, No. 4 and No. 5 Bores showed that, in their vicinity, the yielding capacity of this aquifer is insignificant and does not exceed 50 to 100 gallons per hour. In No. 6 Bore, however, pump tests indicate a supply in the order of 32,000 gallons per hour.

Very large supplies have been proved for the Lower Cretaceous aquifer. The total capacity of the *whole* aquifer thickness in No. 2, No. 4, No. 5 and No. 6 Bores, is of the following magnitude:—

No. 2 Bore: 37,000 gallons per hour.
No. 4 Bore: 45,000 gallons per hour.
No. 5 Bore: 33,000 gallons per hour.
No. 6 Bore: 25,000 gallons per hour.

(Because of increasing salinities, no pump tests were carried out in No. 6 Bore below 520 feet.)

In No. 3 Bore the yield, as determined by a bailing test, was only 150 gallons per hour. This is caused by the very low permeability of the Lower Cretaceous aquifer in this locality.

In No. 1 Bore no water of any consequence was encountered above 837 feet.

DIRECTION OF GROUNDWATER MOVEMENT.

Underground water moves in the direction of the hydraulic gradient. Unconfined water will move from high to low areas in the water table and confined water from areas of high to those of low hydrostatic head.

The water table profile of the shallow, Quaternary aquifer and the hydraulic gradient of the Lower Cretaceous aquifer, are shown in Plate 4B. It will be seen that the water table has a uniform gentle slope to the west. The difference in elevation between No. 3 Bore and No. 6 Bore, a distance apart of 7 miles, is 69 feet, a gradient of approximately 10 feet per mile.

The hydraulic gradient has a similar, although variable, slope to the west. Between No. 2 and No. 3 Bores the gradient is 28.5 feet per mile; between No. 3 and No. 4 Bores it is 6.5 feet per mile; and between No. 4 and No. 6 Bores, it averages little more than 1 foot per mile.

The hydraulic gradients of both aquifer systems are indicative, therefore, of a general movement of the underground waters from east to west.

INTAKE AREAS

The underground water reservoirs underlying the coastal plain between Byford and Medina are recharged by direct precipitation, or by precipitation and infiltration of surface waters.

It is considered probable that the intake area for the Lower Jurassic aquifer in No. 1 Bore is along the Darling Fault and that recharge is effected, principally by direct downward percolation of rainwater, which may be added to by seepage from water courses crossing the fault zone (Plate 3).

The intake area for the Lower Cretaceous aquifer is the coastal plain, some 4 miles west of the Darling Fault. It is adjacent to and west of the fault passing through No. 2 Bore site (Plate 3). It is believed that seepage from surface water courses forms a major contribution to the total amount of recharge. The disappearance of these surface waters along a line coinciding with the fault has previously been mentioned. The other source of recharge is rain falling directly on the outcrop area of the aquifer.

The Quaternary aquifer is recharged exclusively by local rainfall, the normal annual precipitation in the area being about 33 inches. A part of this water finds its way, by seepage through the superficial, unconsolidated deposits, to the zone of saturation and from there moves down the slope of the water table to points of discharge. The proportion of rainfall that actually reaches the water table varies with local conditions and depends on a number of factors, such as the amount and intensity of rainfall, the physical characteristics of the soil and the underlying rocks, surface run-off and evapotranspiration.

For the area under consideration, surface run-off into claypans, etc., occurs locally, but is not of major importance. On the other hand, a high rate of evapotranspiration is indicated by the large tracts occupied by native vegetation and the shallow depth of the water table.

Considering the small supplies obtainable from this aquifer (except in No. 6 Bore) and the relatively high regional rainfall, the proportion of rainfall that becomes recharge must be regarded as small.

QUALITY AND SUITABILITY OF THE UNDERGROUND WATER

The chemical character of the underground waters is indicated by analyses of samples taken from the principal aquifer intervals on completion of pump tests. Table 5 shows that the waters are essentially sodium chloride and bicarbonate (HCO_3) waters. Concentrations of total dissolved solids range from 300 p.p.m. to 2,580 p.p.m.

Lower Jurassic Aquifer

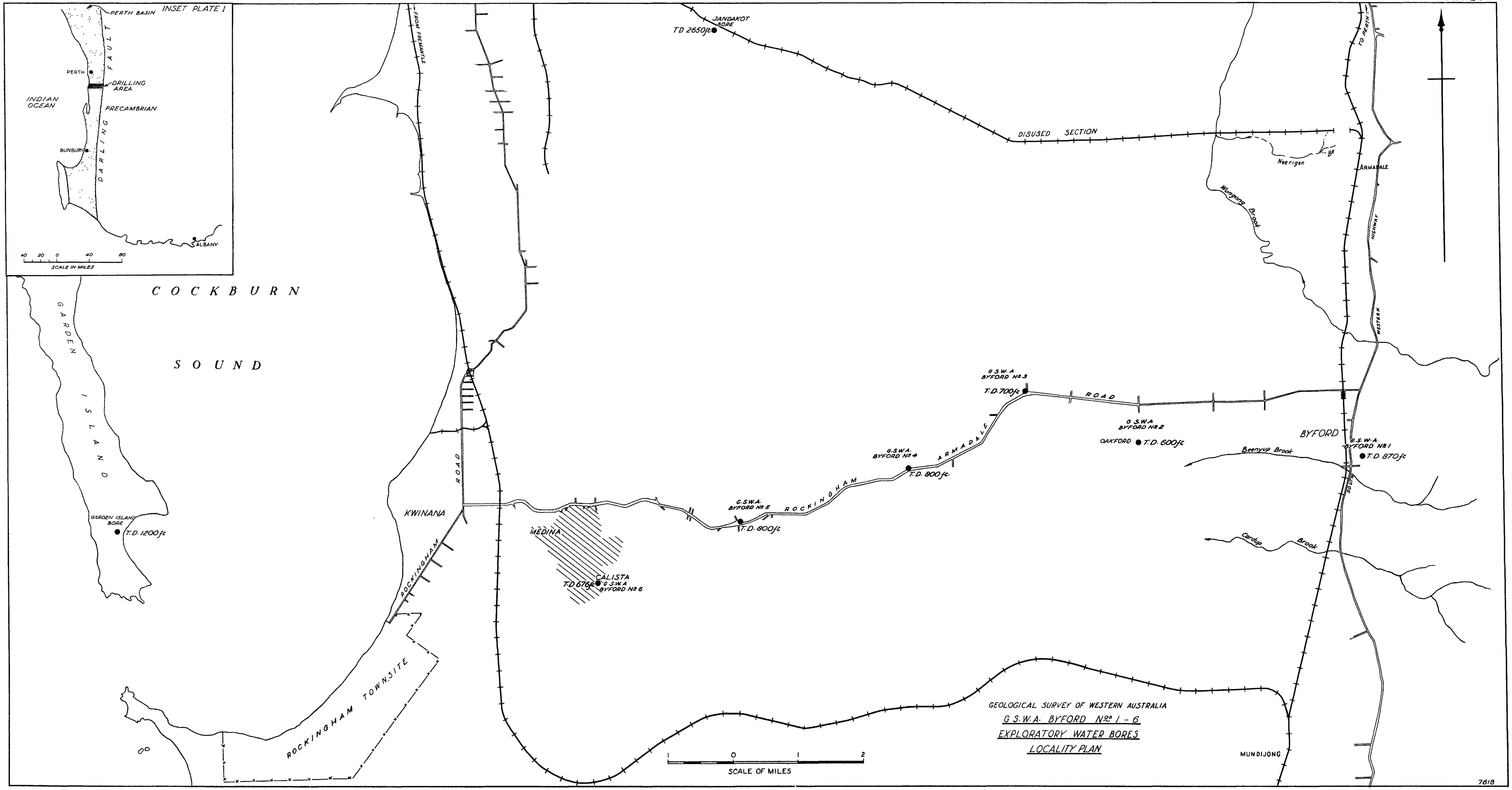
This aquifer occurs only in No. 1 Bore, in which the chemical character of the water shows its suitability for irrigation. It could also be used for domestic purposes, although the total dissolved salt content is near the upper permissible limit.

Lower Cretaceous Aquifer

The water from this aquifer, intersected in No. 2 to No. 6 Bores, shows considerable variations in chemical character.

Firstly there is a marked increase in the concentration of dissolved solids from east to west, i.e., from No. 2 to No. 6 Bore. This relationship becomes particularly noticeable when the salinities from the bottom sections of the aquifer are compared. It can be seen from Table 5 that the concentration gradually increases from 710 p.p.m. in No. 2 Bore, to 2,580 p.p.m. in No. 6 Bore. In No. 3 Bore the total dissolved solids in the bottom section of the aquifer amounted to 2,300 p.p.m., an abnormally high value, explained by the very low permeability of the aquifer interval, causing differential movements of the water in this particular area.

Secondly, there is a considerable increase in salinity from the top to the bottom sections of the aquifer. In No. 2 Bore, which is close to the intake area, no increase is noticeable, but it becomes significant in No. 4, No. 5 and No. 6 Bores. Thus, in No. 4 Bore there is an increase in total dissolved solids from 300 p.p.m. to 890 p.p.m., in No. 5 Bore from 1,080 p.p.m. to 1,480 p.p.m. and in No. 6 Bore from 1,940 p.p.m. to 2,580 p.p.m.


INSET PLATE 1
PERTH BASIN
FAULT
PERTH
DRILLING AREA
INDIAN OCEAN
PRECAMBRIAN
DARLING
BUNBURY
ALBANY
40 20 0 40 80
SCALE IN MILES
COCKBURN
SOUND
GARDEN ISLAND
GARDEN ISLAND BORE
T.D. 1200 ft
FROM FREMANTLE
JANDAKOT BORE
T.D 2650 ft
DISUSED SECTION
Neerigen Bk
ARMADALE
TO PERTH
Wungong Brook
HIGHWAY
WESTERN
SOUTH
G.S.W.A. BYFORD No 3
T.D.700 ft
ROAD
G.S.W.A. BYFORD No 2
OAKFORD T.D. 600 ft
BYFORD
G.S.W.A. BYFORD No 1
T.D. 870 ft
Beenyup Brook
G.S.W.A. BYFORD No 4
T.D. 800 ft
ARMADALE
ROCKINGHAM
G.S.W.A. BYFORD No 5
T.D. 800 ft
ROAD
KWINANA
MEDINA
CALISTA
T.D 676 ft
G.S.W.A BYFORD No 6
ROCKINGHAM
Cardup Brook
ROCKINGHAM TOWNSITE
MUNDIJONG
1 0 1 2
SCALE OF MILES
GEOLOGICAL SURVEY OF WESTERN AUSTRALIA
G.S.W.A. BYFORD Nos 1 - 6
EXPLORATORY WATER BORES
LOCALITY PLAN
7618


GEOLOGICAL SURVEY OF WESTERN AUSTRALIA
G.S.W.A. BYFORD BORES Nos 1-6
STRATIGRAPHIC CORRELATION
BYFORD No 6 BORE
Elevation 25'
0 feet SEA LEVEL
37
65
156
270
490
520
542
T.D. 676
BYFORD No 5 BORE
Elevation 71'
81
123
250
474
528
623
785
T.D 800
BYFORD No 4 BORE
Elevation 91'
95
132
325
430
457
632
T.D 800
BYFORD No 3 BORE
Elevation 77'
87
232
297
499
T.D 700
BYFORD No 2 BORE
Elevation 68'
32
82
121
170
543
T.D 600
BYFORD No 1 BORE
Elevation 214'
25
99
135
SEA LEVEL
0 feet
837
858
T.D. 870
200
100
0
100
200
300
400
500
600
700
800
SCALE OF CHAINS
40
0
40
80
LEGEND
LIMESTONE, OR CARBONACEOUS SANDSTONE
SAND, SANDSTONE
SILTSTONE AND CLAYSTONE INTERBEDDED, OR CLAYEY SILTSTONE.
CLAYSTONE
FORMATION UPPER BOUNDARY SHOWN THUS:-
OSBORNE FORMATION
SOUTH PERTH FORMATION
LOWER JURASSIC
7819

GEOLOGICAL SURVEY OF WESTERN AUSTRALIA
GEOLOGICAL CROSS SECTION ACROSS THE PERTH BASIN
BETWEEN BYFORD AND GARDEN ISLAND

7820


GEOLOGICAL SURVEY OF WESTERN AUSTRALIA
G.S.W.A. BYFORD BORES Nos 1-6
A: AQUIFER CORRELATION
BYFORD No 6 BORE
BYFORD No 5 BORE
BYFORD No 4 BORE
BYFORD No 3 BORE
BYFORD No 2 BORE
BYFORD No 1 BORE
Ground Surface
Quaternary - Recent Aquifer (unconfined)
Aquiclude
Lower Cretaceous Aquifer (confined)
Aquiclude
Lower Jurassic Aquifer
FAULT
SCALE OF CHAINS
400
0 feet
400
800
1200
B: HYDRAULIC GRADIENTS
Quaternary - Recent Aquifer : Slope of water table
Lower Cretaceous Aquifer : Hydraulic Gradient
Static Level of Lower Jurassic Aquifer
200
150
100
50
0 feet
50
7821

The salinity variations within the aquifer are large enough to affect the suitability of the waters for specific purposes. To the east, i.e., in Bores No. 2 to No. 4, the quality is suitable for domestic purposes. In No. 5 Bore only the water from the top section of the aquifer reaches that standard, while in No. 6 Bore the concentration of dissolved solids exceeds the limit normally accepted for permanent domestic use. The water, however, is of excellent stock quality and could possibly be used to irrigate more salt-tolerant crops on suitable soils.

Quaternary Aquifer

On account of the insignificant yields obtained, no complete analyses were made for No. 3, No. 4 and No. 5 Bores. The concentrations of total dissolved solids and sodium chloride are shown in Table 3.

TABLE 3. QUATERNARY AQUIFER; SALINITIES

No. of Bore	3	4	5
	p.p.m.	p.p.m.	p.p.m.
Total Dissolved Solids	1,400	560	1,150
Sodium Chloride	1,080	340	670

The shallow groundwater from these bores is generally not suitable for domestic use because of discoloration by organic matter. Also, the total salt content is either in excess of, or near to the upper limit for that purpose. The water is suitable for watering all stock and most garden crops.

The large supply from this aquifer in No. 6 Bore is low in salinity and suitable for all purposes (Table 5).

CONCLUSIONS

The objective of the exploratory drilling programme outlined at the beginning of this report, has been achieved and important hydrological information has been gained in this part of the Perth Basin. The fact that it was possible to differentiate and correlate aquifer systems and to establish a pattern of salinity distribution will give valuable guidance in the future search for underground water.

The results obtained are most conclusive in the area between Medina-Calista and Oakford. Between Oakford and Byford the interpretation of the hydro-geology had to be based on information from one bore only, with supporting evidence from a bore outside the drilling area.

The practical results of the exploratory work are summarised below:—

For the area between Medina-Calista and Oakford, underground water is available from two independent, superimposed aquifers. The water table of the uppermost shallow aquifer is encountered at depths varying from 5 feet to 40 feet below the surface, but in order to penetrate the whole thickness of the aquifer, bores may have to be drilled to a depth of as much as 150 feet.

The supplies from this aquifer are generally small, not exceeding 1,000 to 2,000 gallons per day. The water is coloured brown by organic matter, but is suitable for stock and watering most garden crops. In the Medina-Calista area large supplies, suitable for domestic and irrigation purposes, are obtainable from this aquifer.

The depth to the second aquifer varies, but gradually increases from east to west, i.e., from less than 50 feet at Oakford to nearly 500 feet at Calista. The quality of the water deteriorates in the same direction and also from top to bottom of the aquifer. However, with the exception of the westernmost portion of the drilled area, the water, at least within the top section of the aquifer, is suitable for all purposes, including domestic use.

The supplies from this aquifer are very large. The water is under pressure and will rise to less than 100 feet below the surface. North and south of Oakford artesian supplies may be obtained.

Between Oakford and Byford it is unlikely that supplies of the order of 8,000 gallons per hour will be obtainable from depths of less than 600 to 800 feet. However, the water from this depth is under pressure and will rise considerably in the bore hole. The water should be usable for irrigation on suitable soils, but is a doubtful source for domestic purposes.

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TABLE 4. RESULTS OF PUMP TESTS

G.S.W.A. Bore Name	Aquifer Section tested (Depth in feet)	Date of Test	Duration of test (hours)	Static Level (feet above/below surface)	Rate of Pumping (galls. per hour)	Draw-down (feet)	Recovery	Remarks
Byford No. 1	837–858	6th-7th May, 1961	34	— 112	8,000	83	3 hours	
Byford No. 2	32–46	22nd-23rd June, 1961	24	at surface	6,120	20	not determined	
	50–82	7th-8th July, 1961	24	+ 6	16,800	28	Do.	Flow approximately 1,500 galls. per hour
	121–170	19th-21st July, 1961	48	+ 16	14,400	91	Do.	Flow approximately 5,000 galls. per hour
	140–150	11th-12th October, 1961	24	+ 16	7,200	110	*	Flow approximately 3,000 galls. per hour. This was a final pump test after bore had been backfilled to 150 ft. Brass screen set from 140 ft.–150 ft.
Byford No. 3		Not Tested	Small supplies, rather saline water					
Byford No. 4	325–430 457–632	30th-31st July, 1962 .... 21st-22nd August, 1962	37 25	— 70 — 68	20,000 25,000	16 35	† 2 hours	
Byford No. 5	474–528 623–785	21st-23rd November, 1962 13th December, 1962	48 24	— 52 — 52	21,000 22,800	26 37	9 minutes 15 minutes	
Byford No. 6	22– 65 70–156 490–520	1st February, 1963 .... 4th March, 1963 .... 26th March, 1963	24 24 24	— 22 — 22 — 13	27,000 5,100 25,500	7 87 16	30 seconds 4 minutes 3 minutes	

* Flow recovered 5 minutes after pumping ceased. † 105 minutes to 1 foot below static level.

TABLE 5. WATER ANALYSES BY GOVERNMENT CHEMICAL LABORATORIES

Exploratory Bore	Byford No. 1	Byford No 2			Byford No. 4		Byford No. 5		Byford No. 6			
Aquifer Section Tested (depth in feet)	837–858	32–46	50–82	121–170	325–430	457–632	474–528	623–785	22–65	70–156	490–520	670–676
Specific conductivity 20°C (micromhos)	....	....	....	....	....	....	2,450	....	....	850	....	3,830
pH	7·7	6·3	7·5	6·6	7·8	7·6	6·7	7·5	7·4	7·3	7·0	8·0
Mineral Matter (p.p.m.)												
Calcium, Ca	4	11	14	11	60	62	54	80	93	67	....	84
Magnesium, Mg	2	20	21	16	6	30	35	52	12	11	....	61
Sodium, Na	342	190	181	189	41	224	288	393	58	126	....	787
Potassium, K	8	9	9	14	3	7	8	11	2	8	....	18
Bicarbonate, HCO_3	244	123	113	107	213	205	167	254	302	257	....	202
Carbonate, CO_3	nil	nil	nil	nil	nil	nil	nil	nil	nil	nil	....	nil
Sulphate, SO_4	26	29	37	29	2	37	33	69	13	less than 1	....	134
Chloride, Cl, (equivalent to)	386	286	279	273	64	402	528	710	104	202	....	1,340
Sodium chloride, NaCl	....	....	....	....	....	....	....	1,170	....	....	1,414	2,210
Nitrate, NO_3	less than 1	less than 1	less than 1	less than 1	less than 1	less than 1	less than 1	less than 1	 2	 2	....	less than 1
Silica, SiO_2	16	73	37	46	14	13	....	19	10	9	....	....
Iron, Fe	....	....	....	....	0·2	0·1	0·05	less than 0·1	0·3	7·7	....	....
Iron Oxide, Fe_2O_3	9	17	3	1	....	....	....	....	....	....	....	....
Aluminium, Al	....	....	....	....	less than 1	less than 1	....	....	....	....	....	....
Aluminium oxide, Al_2O_3	7	14	less than 1	24	....	....	....	....	....	....	....	....
Total											1,940*	2,700*
By summation	1,044	772	694	710	403	981	1,113	1,588	596	684	....	....
By evaporation	....	....	....	....	300	890	1,080	1,480	460	560	....	2,580
Hardness (calculated as $CaCO_3$)												
Total hardness	18	108	121	93	175	278	279	414	281	212	....	461
Bicarbonate (temporary) hardness	18	101	93	89	175	168	137	208	248	211	....	166
Non-carbonate (permanent) hardness	nil	7	28	4	nil	110	142	206	33	1	....	295
Calcium hardness	10	27	36	29	150	155	135	200	232	167	....	210
Magnesium hardness	8	81	85	64	25	123	144	214	49	45	....	251

*(By conductivity)

PROGRESS REPORT ON DRILLING FOR WATER IN THE GNANGARA LAKE AREA NEAR PERTH

By K. H. Morgan

During 1961 the Metropolitan Water Supply, Sewerage and Drainage Department requested an examination of the shallow ground water resources of the area approximately 10 miles north of Perth near Gnangara Lake as a possible supplement to Perth's water supply. A daily requirement of 17.5 million gallons was envisaged. As a result a field survey was made, and test drilling was recommended, initial approval being for six bores. These indicated the occurrence of excellent water over an extensive area and a further six bores were then proposed, the whole drilling being on a rectangular grid with a two-mile spacing (see Plate 5). To date, 11 bores have been completed.

Besides the test drilling, seasonal fluctuations in water levels and salinities of bore and surface waters, have been observed and a census made of the bores and wells in the area. Drilling was done by Mines Department percussion rigs.

Sludge samples were collected at regular five foot intervals, at each change of formation noted by the driller, and at two foot intervals when in clean, coarse-grained sand. Each sample was hand sieved and some sent for mechanical analysis in the laboratory.

Water samples were taken at regular 10 feet intervals and tested for ferrous iron and total dissolved solids. Samples from pumped bores were sent for complete chemical analysis.

The stratigraphic succession is as follows:—

Name of Unit	Description	Thickness (feet)
"Badgerup Sand"	Yellow, well sorted, medium-grained sand	0–210
"Bassendean Sand"	Grey, clean to clayey, medium-grained sand	0–168
"Gnangara Sand"	Coarse and very coarse, clean to clayey, pebbly sand	5–61
Coastal Limestone	Sandy limestones and calcarenite	0–60
Molecap Greensand	Clean to clayey, glauconitic sand	0–55 (+)
Osborne Formation	Dark-green, clayey, glauconitic sand	0–50 (+)

Average annual rainfall is approximately 32 inches per year. Surface drainage is only from shallow dug drains, and runoff is small, but to the eastward there is extensive seepage into the Swan River and Ellen Brook. In winter the water table rises above surface in many places to form shallow lakes and swamps, which mostly become dry in the summer as a result of the decline of the water table and evaporation. Because of evaporation, salinity of some surface waters rises to 1,000 parts per million total dissolved solids during summer months.

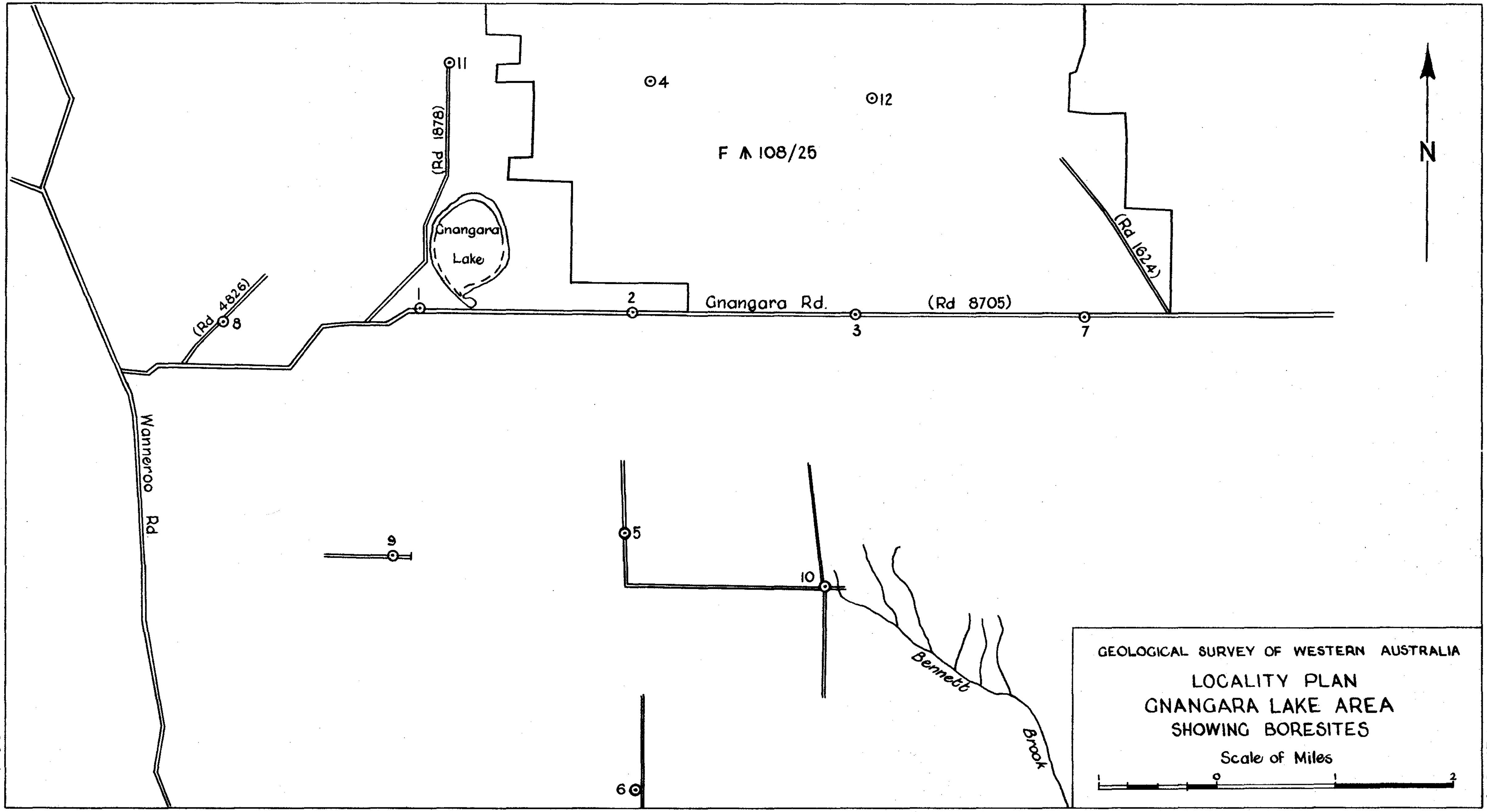
The water table occurs at depths ranging from the surface to more than a 100 feet below the surface (see accompanying table), but is generally at a depth of less than 20 feet. Its height above sea level varies from 110 feet in Bore No. 6, the most southerly of the bores, to 170 feet in Bore No. 4, thus indicating a southward gradient of about 10 feet per mile over a distance of six miles. The east and west gradients have not been reliably determined by drilling, but from regional information are of similar order. It steepens to 20 feet per mile along the western side of the area.

Including the limestones and the sand section there is an average thickness of 150 feet of aquifer which has been proven by drilling. In all bores there are clean, coarse-grained sands ranging from five to 67 feet in thickness that could be effectively developed.

Average salinity of the waters is 470 parts per million total dissolved solids. There is no increase in salinity with depth and there appear to be no bodies of saline water nearby.

The iron content is usually above one part per million and the water has a slight brown colouration and slightly sulphureous odour in the upper sections. A sulphureous odour and a discolouration have been noted during a trial pumping test from the aquifer between 110 and 150 feet on Bore No. 1.

The investigation to date has confirmed that a large volume of water of reasonable quality occurs in the Gnangara area, and perennial recharge should be enough to support a substantial draw-off. The extent of this groundwater body and the position of the intake areas have not yet been defined, and further drilling will be needed. Assessment of reserves would be aided by an investigation of the amount of local rainfall penetrating into the sands and reaching the water table, examination of the transpiration effects of the nearby pine forests, and long-term observation of water level fluctuations.



GEOLOGICAL SURVEY OF WESTERN AUSTRALIA
LOCALITY PLAN
GNANGARA LAKE AREA
SHOWING BORESITES
Scale of Miles
1
0
1
2
N
F A 108/25
Gnangara Lake
Gnangara Rd.
(Rd 8705)
(Rd 1878)
(Rd 4826)
(Rd 1624)
Wanneroo Rd.
Bennett Brook
1
2
3
4
5
6
7
8
9
10
11
12

PLATE 5

7914

TABLE SHOWING THE PRINCIPAL BORE DATA—GNANGARA LAKE WATER DRILLING PROJECT

Bore No.	Reduced Surface Level above M.S.L. (Fremantle)	Standing water Level in Completed bore	Total Depth	Total Thickness of Aquifer	Principal Aquifers		Average Salinity Total Dissolved Solids
					Thickness	Depth Below Surface	
	(feet)	(feet)	(feet)	(feet)	(feet)	(feet)	(p.p.m.)
1	158·91	21	215	190 (+)	50	110–160	550
2	154·49	11	171·75	150	10	100–110	500
3	150·96	8	182	128	30	80–110	800
4	182·99	15	221	88	35	85–120	350
5	140·08	15	164	145	22	72–94	550
6	115·28	6	140	83	10	105–115	330
7	not determined	3	340	287	20	115–135	315
8	not determined	88	303	187	10	227–237	730
9	not determined	91	270	144	67	170–237	450
10	not determined	4	144	116	5	95–100	450
11	not determined	17	252	178	20	130–165	400
12	not determined	14	204	176	20	100–120	220

PROGRESS REPORT ON DRILLING FOR WATER TO SUPPLEMENT THE GERALDTON TOWN WATER SUPPLY

By A. D. Allen

ABSTRACT

The present source at Wicherina of groundwater for the Geraldton Town Water Supply, is capable of only limited expansion. To meet increasing immediate demands and estimated supplementary requirements of 1,700 million gallons per annum in 1982-83, other sources of groundwater are required. Twenty test bores drilled within a 40 mile radius of Geraldton have shown that the best potential area is in the vicinity of Lake Allanooka, 35 miles south-east. Here relatively shallow, unconfined groundwater, ranging in salinity from 530 to 1,000 p.p.m. total dissolved solids, occurs in the Yarragadee Formation. Pumping tests at rates of between 6,000 and 25,000 gallons per hour indicate that the aquifer has a variable yield. Investigation is still proceeding, but it is reasonably certain that a supplementary source of groundwater has been found.

INTRODUCTION

Geraldton (population about 12,000) is situated on Champion Bay, about 310 miles north of Perth. The town serves as an outlet port for the surrounding agricultural and mining districts, and is also the centre of a local crayfishing industry.

Average rainfall is 18.34 inches, but because of the nature of the catchment rocks and the climatic conditions, run-off is usually saline and the local rivers are unsuitable as sources of domestic water. In addition, the groundwater obtained in the vicinity of the town is too saline for domestic use.

The present source of the Geraldton town water supply is at Wicherina, 28 miles to the east, adjoining the Geraldton-Mullewa road, where water is obtained from two dams on Wicherina Brook (an unusual non-saline catchment) and from a number of bores. The dams have a combined capacity of about 120 million gallons and provide 5 to 20 per cent. (depending on rainfall) of the present water supply. The bulk of the water is supplied from groundwater sources.

At Wicherina, groundwater is obtained from two distinct areas, the South "Basin" in the vicinity of Wicherina Brook and the North "Basin" on the northern side of the Geraldton-Mullewa road. Formerly the South "Basin" supplied the greater part of the required groundwater, but since 1928 the water table has dropped by 30 feet, and saline water has intruded the aquifers from the east rendering many former production bores too saline for town use. Since 1959 the North "Basin" has been the main source of supply, but the nature of the aquifers and the depth from which water has to be pumped, makes production difficult and expensive.

REQUIREMENTS

The population of Geraldton is at present increasing at the fast rate of 5 per cent. per annum. Assuming a rate of increase of 4.5 per cent. per annum the Public Works Department estimates that in 1982-83 (20 years) the population will be about 28,700. Moreover, provided that water from the present Wicherina Scheme can be maintained at 10 million gallons per week, then a further 32.4 million gallons per week or approximately 1,700 million gallons per year will be required from a supplementary source.

DRILLING PROGRAMME

In April, 1962, the Mines Department began drilling in the area near Lake Allanooka with the object of locating further groundwater supplies. Six exploratory bores were drilled by contract and at the completion of these bores in July, 1963, a further seven bores were drilled under two contracts, one for five bores near Lake Allanooka and one for two bores near Mt. Kenneth.

The programme was extended by the Public Works Department using its own plants. Three bores were drilled in the Wicherina area and seven sites proposed in the vicinity of Lake Allanooka. Plate 6 shows the location of the various bores.

At the time of writing (January, 1964) all the Mines Department drilling has been completed, and of the seven Public Works Department bores four have been completed, two are in progress and one remains to be drilled. Preliminary exploratory work is expected to be complete by March and the results will be published in a final report.

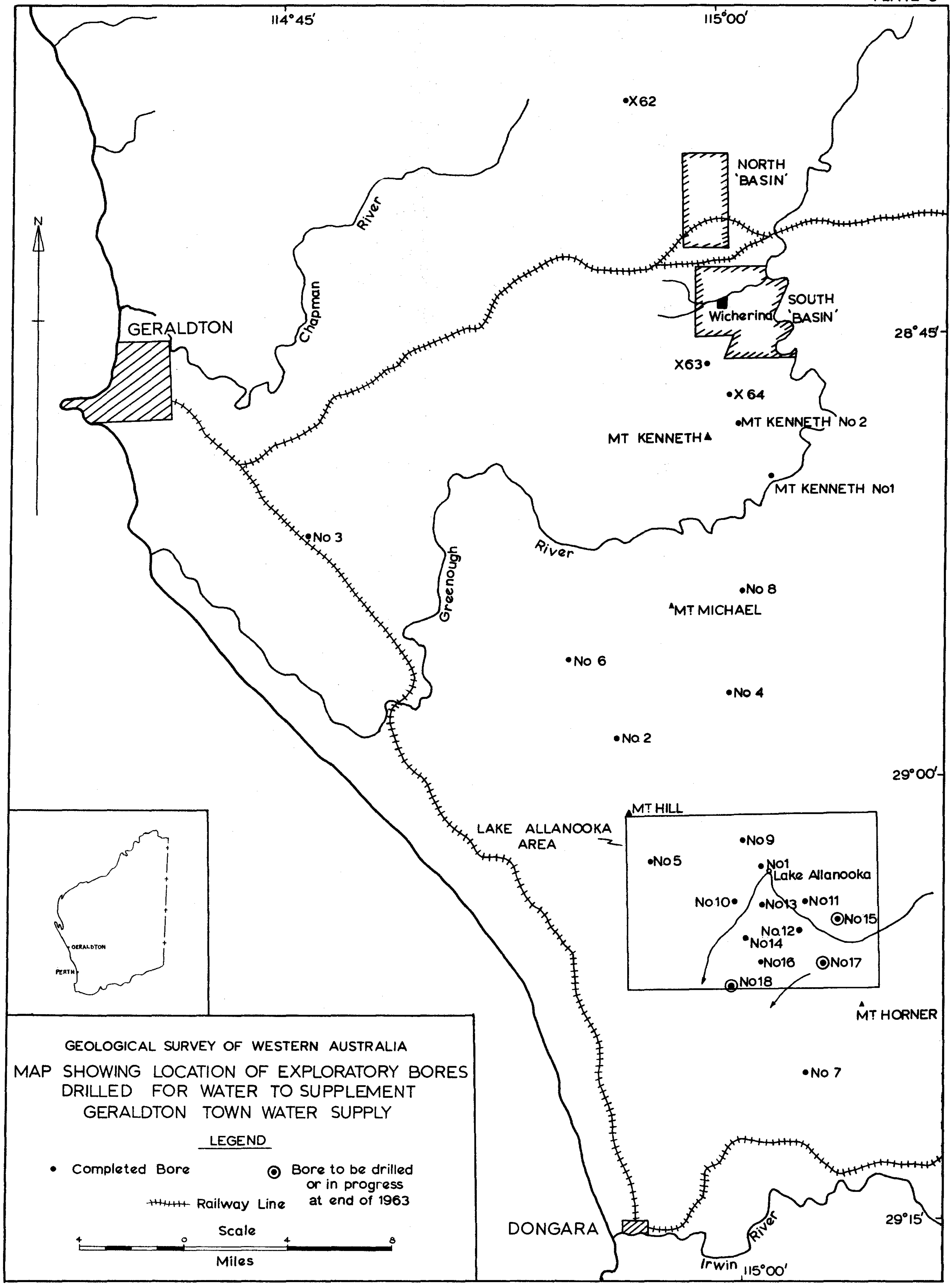
(5) 83541

TABLE 1. SHOWING THE PRINCIPAL BORE DATA OF BORES DRILLED FOR WATER TO SUPPLEMENT GERALDTON TOWN WATER SUPPLY

Bore Name	Commenced	Completed	Co-ordinates		Approx. Reduced Level of Bore Collar	Bore Depth feet	Depth of Main Aquifer below Surface feet	Thickness feet	Formation	Nature of Supply	Rest Level Feet Below Surface	Salinity p.p.m. T.D.S.*	Tested Yield galls per hour	Drawdown feet
			Latitude	Longitude										
Allanooka No. 1	1/4/62	3/9/62	29° 02′ 50″	115° 01′ 25″	344	1,000	43–335	292	Yarragadee Formation	Non-pressure	43′ 0″	540	25,000	6
Do. 2	19/9/62	12/12/62	28° 58′ 30″	114° 55′ 10″	408	645	350–390	40	Moonyoonooka Sandstone	Pressure	216′ 0″	690	6,000	20
Do. 3	14/11/62	27/1/63	28° 51′ 40″	114° 44′ 35″	65	290	55–200	145	Coastal Limestone	do.	23′ 0″	2,708	....	....
Do. 4	4/2/63	4/7/63	28° 57′ 35″	114° 59′ 10″	736	1,000	903–935	32	Moonyoonooka Sandstone	do.	452′ 0″	1,380	....	....
Do. 5	4/2/63	5/4/63	29° 02′ 45″	114° 57′ 15″	323	640	169–475	306	Yarragadee Formation	Non-pressure	166′ 0″	730	6–7,000	35–40
Do. 6	19/6/63	17/7/63	28° 56′ 00″	114° 53′ 25″	473	350	No significant supply	....	....	....	....	....	....	....
Do. 7	9/12/63	16/12/63	29° 09′ 40″	115° 02′ 15″	252	350	115–240	125	Yarragadee Formation	Non-pressure	109′ 6″	690	....	....
Do. 8	1/10/63	25/10/63	28° 53′ 45″	114° 59′ 05″	670	443	345–443	93	Moonyoonooka Sandstone	Pressure	318′ 3″	4,300	....	....
Do. 9	5/11/63	17/11/63	29° 02′ 05″	114° 59′ 30″	562	450	275–438	163	Yarragadee Formation	Non-pressure	250′ 2″	530	....	....
Do. 10	19/11/63	27/11/63	29° 04′ 05″	114° 59′ 50″	273	450	122–450	328	do.	do.	126′ 1″	750	....	....
Do. 11	3/12/63	10/12/63	29° 04′ 05″	115° 02′ 10″	425	350	125–137	12	do.	do.	115′ 4″	550	....	....
Do. 12	19/11/63	11/12/63	29° 04′ 50″	115° 01′ 45″	369	500	95–129	34	do.	do.	69′ 6″	590	....	....
Do. 13	19/11/63	9/12/63	29° 04′ 10″	115° 00′ 40″	300	450	126–450	324	do.	do.	130′ 6″	1,100	....	....
Do. 14	1/10/63	5/11/63	29° 05′ 05″	115° 00′ 10″	300	450	157–450	293	do.	do.	157′ 0″	670	15,000	7
Do. 16	28/8/63	31/10/63	29° 05′ 50″	115° 00′ 40″	300	715	165–655	490	do.	do.	170′ 0″	620	10,500	32
Mt. Kenneth No. 1	21/10/63	10/11/63	28° 49′ 50″	114° 59′ 30″	430	160	80–160	80	Moonyoonooka Sandstone	Pressure	67′ 0″	3,810 (approx.)	....	....
Do. 2	8/9/63	16/10/63	28° 48′ 10″	114° 58′ 20″	651	510	358–510	152	do.	do.	280′ 0″	800 (approx.)	....	....
Do. X62	21/11/62	8/2/63	28° 36′ 50″	114° 56′ 45″	630	400	318–400	82	Tumblagooda Sandstone	do.	57′ 4″	5,880 (approx.)	....	....
Do. X63	16/5/63	23/8/63	28° 46′ 40″	114° 00′ 00″	820	1,013	No significant supply	....	....	....	....	....	....	....
Do. X64	13/6/63	30/8/63	28° 47′ 15″	114° 00′ 40″	765	510	485–510	25	Moonyoonooka Sandstone	Pressure	419′ 0″	950	....	....

* 1,000 parts per million total dissolved solids is the desirable upper limit in water used for domestic supplies.

PLATE 6


GEOLOGICAL SURVEY OF WESTERN AUSTRALIA
MAP SHOWING LOCATION OF EXPLORATORY BORES DRILLED FOR WATER TO SUPPLEMENT GERALDTON TOWN WATER SUPPLY
LEGEND
Completed Bore
Bore to be drilled or in progress at end of 1963
Railway Line
Scale
4 0 4 8
Miles
114°45'
115°00'
28°45'
29°00'
29°15'
N
GERALDTON
DONGARA
PERTH
Chapman River
Greenough River
Irwin River
NORTH 'BASIN'
SOUTH 'BASIN'
Wicherina
X62
X63
X 64
MT KENNETH
MT KENNETH No 2
MT KENNETH No1
No 3
No 8
MT MICHAEL
No 6
No 4
No 2
MT HILL
LAKE ALLANOOKA AREA
No 9
No 5
No1
Lake Allanooka
No10
No13
No11
No15
No12
No14
No16
No17
No18
MT HORNER
No 7

7902

GEOLOGY AND HYDROLOGY

Geraldton lies at the northwestern end of the Perth Basin in an area which has had a complicated geological history. The rocks range in age from ?Lower Silurian to Recent and are better exposed in this region than in most places in the Perth Basin. Moreover, the rocks are moderately known from a number of deep bores in the region.

The composite geological succession in the area is as follows:—

Recent	Alluvium and coastal sand dunes
Pleistocene-Recent	Coastal Limestone
Unconformity	
Upper Jurassic-Lower Cretaceous	Yarragadee Formation
Lower Jurassic-Middle Jurassic	{ Champion Bay Group { Chapman Group
Unconformity	
Lower Triassic	Kockatea Shale
Unconformity	
Lower Permian	Undifferentiated sandstones and siltstones
Lower Permian	Holmwood Shale
Lower Permian	Nangetty Formation
Unconformity	
?Lower Silurian	Tumblagooda Sandstone
Unconformity	
Archaean	Basement complex

All the listed rock units were drilled and found to contain some supplies of groundwater. Important aquifers occur in the Lower Permian undifferentiated sandstones and siltstones, in the Moonyoonooka Sandstone of the Champion Bay Group, in the Yarragadee Formation and in the Coastal Limestone. Of these the Yarragadee Formation is by far the most widespread and important aquifer.

DRILLING RESULTS

The bores were drilled by percussion cable-tool rigs. Sludge samples for logging were collected every 10 feet and at each change of stratum. Where practicable, a water sample was taken every 10 feet and the salinity determined and in most cases a water sample from the main aquifer was taken for complete analysis.

Table 1 gives the more important bore data gained so far.

Within the region the best potential for large supplies of good quality groundwater is from the Yarragadee Formation in the vicinity of Lake Allanooka, 35 miles southeast of Geraldton. Away from this vicinity, groundwater is too deep, too saline or of limited occurrence, although more good quality groundwater is expected as investigations extend further afield.

In the vicinity of Lake Allanooka there is a thick aquifer in the Yarragadee Formation which on pumping tests has yielded between 6,000 and 25,000 gallons per hour of groundwater ranging in salinity from 530 to 1,100 parts per million total dissolved solids. The groundwater table which slopes rather steeply to the southwest occurs at moderate depth and appears to receive recharge from rainfall.

The Lake Allanooka Area (see Plate 6) was thought to have been underlain by a thick variable sequence of clayey sandstones. However, results shown that the structure of the area is probably modified by faulting and that about half the area outlined is underlain by a thick sequence of siltstones with only minor sandstones and is unsuitable for water production. Therefore, although there are considerable reserves in the potential area, further test drilling may have to be carried out in the future.

CONCLUSIONS

Drilling is not yet complete, but it is reasonably certain that a satisfactory supplementary source of groundwater has been found, capable of meeting Geraldton's expected requirements.

A PRELIMINARY APPRAISAL OF ENGINEERING GEOLOGY OF WAROONA DAM SITE

By F. R. Gordon

ABSTRACT

Immediately before construction commenced at Waroona dam site, geological examination of outcrops and cores from over 170 auger bores established that unstable conditions existed that would endanger the structure. Remedial work would have involved an extensive cut-off trench but from geological considerations a shift of the centre line was proposed and accepted, which obviated much of the extra work.

INTRODUCTION

A dam to supply irrigation water to the Waroona district is proposed for a site on Drakes Brook 3½ miles east of Waroona township (Hamel 1-mile Military Map Sheet, grid reference 980397). Access to the site is gained from the Waroona-Samson Brook Dam road at a point 4½ miles from Waroona, thence by bush track one mile to the site.

Over 170 Gemco auger bores had been drilled by the Public Works Department on the proposed foundation and borrows areas of the dam site, and laboratory testing had been carried out on undisturbed sample cores from the vicinity of the cut-off trench, when a request was received by the Geological Survey of W.A. for a general check on the geology of the site.

Remnants of undisturbed cores from the cut-off trench were geologically logged and, in spite of the fact that they had dried out and had deteriorated due to handling, it was obvious that a stability problem existed due to the presence of permeable material in a weathered sequence underlying the foundation area.

This report summarises the results of a brief and limited geological survey, and contains recommendations affecting the location of the dam and foundation treatment. It is emphasised that the best time for geological appraisal is in the reconnaissance stage of investigation and not, as in the present case, immediately before construction commences.

SITE GEOLOGY

Topography

The proposed dam site is in a valley constriction, immediately downstream of the junction that a remarkably straight, southwesterly-flowing tributary makes with the westerly-flowing main stream of Drakes Brook. The combined streams then flow in a general southwesterly direction through the proposed site. Due to the necessity of building in a valley constriction, the areas in which a dam can be constructed are limited. The valley cross section is largely symmetrical at the natural surface, but the subsurface profile on solid rock is asymmetric and irregular, and reflects the erodability or susceptibility to weathering of different types of rock.

Surficial Geology

Examination of river valleys over an area of 3,000 yards by 1,000 yards revealed only 10 isolated outcrops of bedcrop. The largest of these was an exfoliation boss of largely massive, coarse grained, granitic gneiss, 220 feet long by 120 feet wide, that occurs 600 feet downstream of the centre line. The foliation strikes at 020 degrees with a dip of 70 degrees to the east. The outcrop is traversed by a pegmatite dyke about 9 feet wide, weathered and eroded two feet deeper than the surrounding gneiss, and this dyke strikes at 070 degrees. Joints are sparse, and the pattern is dominated by exfoliation joints, parallel to the present outcrop surface.

A dense, dark green amphibolite, consisting largely of hornblende, shows as a discontinuous outcrop on the northwest bank of the stream through the foundation area of the dam. The outcrop is up to 40 feet wide, and the original position of the offtake pipe was largely along the strike of the amphibolite ridge at 010 degrees. This would have involved heavy rock excavation to place the pipe, which was avoided by a westerly pivot of the pipe direction on the upstream control tower, which in turn meant a shift of about 30 feet at the downstream end. Auger boring along the new alignment showed only one location where rock was within 20 feet of the surface. This emphasises the long, narrow, ridge-like nature of the amphibolite band, which is hard and dense and shows a pronounced lineation favoured by jointing at 010 degrees, with a vertical dip. Three other outcrops of amphibolite were also noted on the northwest bank, and these all showed a vertical dip and a foliation direction of between 010 degrees and 025 degrees.

There are no outcrops on the southeast side of the valley, but a well defined band of quartz boulders trends at 010 degrees over a distance of 200 feet in a position half way up the southwest abutment.

Outcrop is also lacking in the valley of the straight, southerly-trending tributary of Drakes Brook, but in the main valley about 400 feet upstream of the junction, a varied outcrop sequence in banded gneiss, 100 feet wide, is visible.

The other outcrop of note is found on the western side of the south borrow pit and this consists of fairly massive amphibolite, 25 feet wide, striking 005 degrees over a distance of 250 feet.

The fact that all outcrops except one are found on the northern sides of the valley is a characteristic of physiographic importance in the South West Division. It is a consequence of dominant chemical weathering of the south or southwest valley flank, while physical processes such as exfoliation are more prominent on the north and north-east slopes. Outcrop conditions are of course influenced by the rock type and physical coherence, but in general, rock will be found closer to the surface on the north and northeast valley sides than on the south and southwest slopes.

The hill tops and valley slopes are covered by massive and pisolitic laterite. In the immediate vicinity of the stream bed this cover had been removed, and underlying highly weathered rock in the form of residual clay has been exposed. Some alluvial material is visible, in the form of a grey-blue silty clay, and an iron-cemented conglomerate is notable especially in the bed of the tributary to Drakes Brook that joins 600 feet upstream of the dam site. This is apparently a surficial layer up to 6 feet thick, and is found only in the immediate valley bottom.

Ground Water and Water Movement

The belt of soil water is mostly confined to a rusty yellow-brown clayey laterite, often pisolitic, that has an average thickness of 5 feet. The uppermost zone of rock weathering is usually an impervious gibbsite-kaolin clay. Permeability then increases with depth, and is greatest in the zone of gradation between weathered and unweathered rock, and most groundwater occurs in that zone. Unweathered rock is relatively impermeable and has a low storage capacity, and water movement is governed by the local joint patterns which vary greatly with the different rock types.

Exfoliation joints largely parallel to the ground or outcrop surface are dominant in areas of massive granitic gneiss, especially on the northern valley slopes. Otherwise major jointing follows foliation, and this means that in solid rock the water passages are running through the proposed dam site, almost at right angles, to the centre line. No estimates of the degree of continuity of the various fractures, or their spacing, width of opening and type of filling, if any, are possible. These are features that could only be determined from a diamond drill hole, and from the cores and from water pressure tests, the pattern would be discernible.

In the weathered rock, water movement is confined by thick overlying impermeable kaolinite and gibbsite clays, which are part of the *in situ* weathering sequence. The upper limit of water movement in the soil profile is usually shown by the presence of iron staining, and this ferruginated zone shows the precipitation of downward moving ferric iron on meeting the acidic ground water. The zone of greatest permeability in gneissic rocks is in the "sandy" phase of rock weathering, where the rock is composed largely of quartz grains and mica plates. To some extent movement will be controlled by foliation or relict schistosity and by some joints at right angles to this direction.

The sequence is shown clearly in Gemco hole 155, on the cut-off trench line at 900 feet, and 95 feet left.

Depth	% Clay	Remarks
8–14½ feet	15·0	Laterite, high in alumina.
14–15 feet	11·0	Kaolin phase, weathered.
19–19½ feet	0·9	Quartzose band.
24–24½ feet	5·9	Ferruginated, top zone of groundwater.
29–29 ft. 8 ins.	1·0	Sandy phase, quartz grains.
34–34 ft. 8 ins.	....	Sandy phase, quartz and mica.
39–39 ft. 11 ins.	3·0	Sandy phase, moderate weathering.
44–44 ft. 9 ins.	3·0	Moderately weathered schistose rock.

Ground water level as recorded by driller—24 feet.

ROCK WEATHERING

The extensive auger borings have shown a considerable variation in the level of subsurface rock, and with a more or less symmetrical valley profile, there are considerable variations in the thicknesses of *in situ* weathered material. The weathering profiles differ with different rock types, but the differences of the products become less accentuated towards the ground surface, and the highest member consisting of massive and pistolitic laterite, usually shows few characteristics of the original rocks.

Massive amphibolite is resistant to chemical decomposition, and often occurs as ridge "spines."

Schistose amphibolite or horneblende schist is prone to chemical and physical breakdown, and some of the deep depressions in the bedrock profile are a result of this. A typical weathering sequence is given, with a geological interpretation of the driller's log in the following table:—

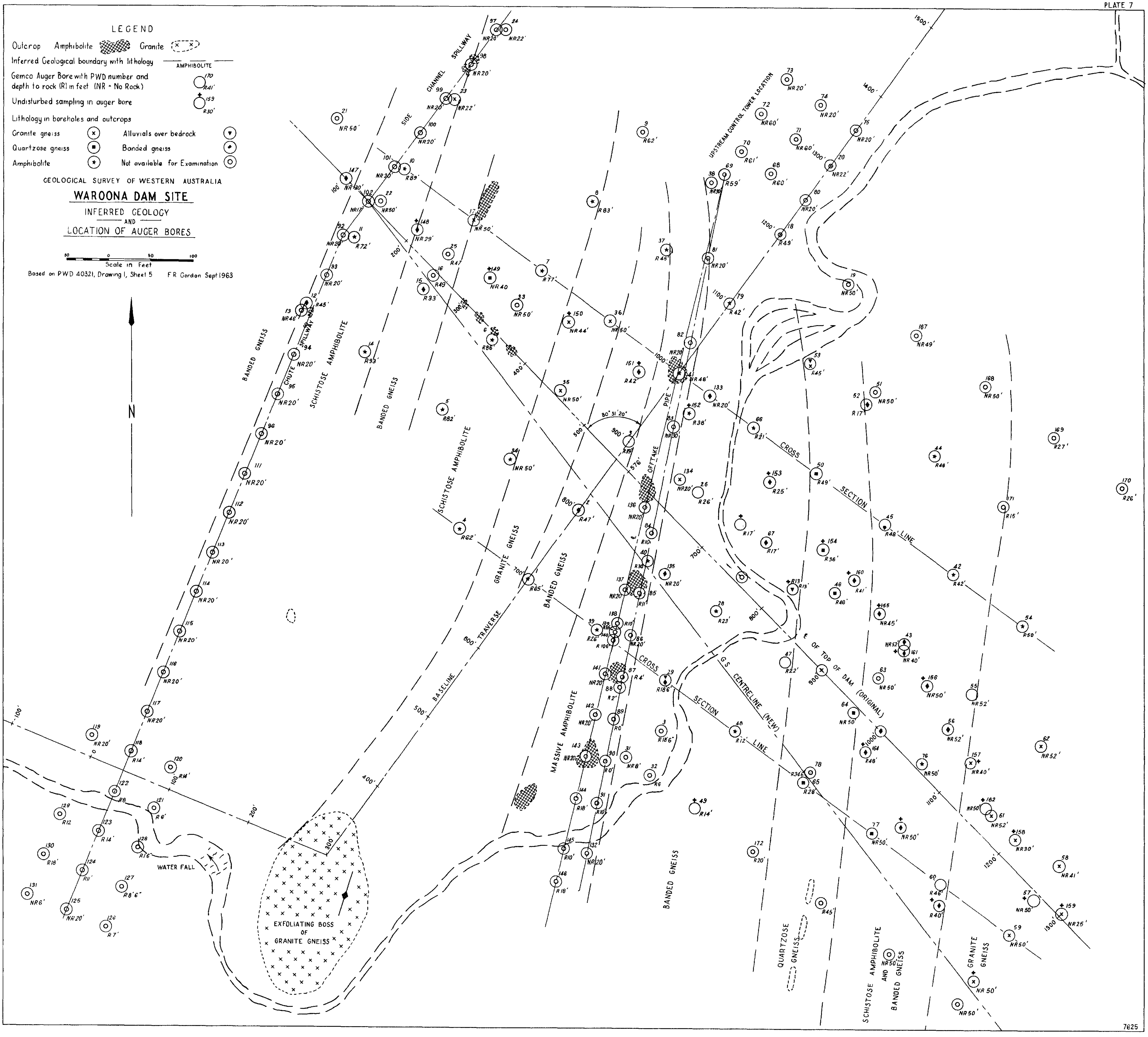
Hole 10. 400 feet right of base line on 1,000 feet.

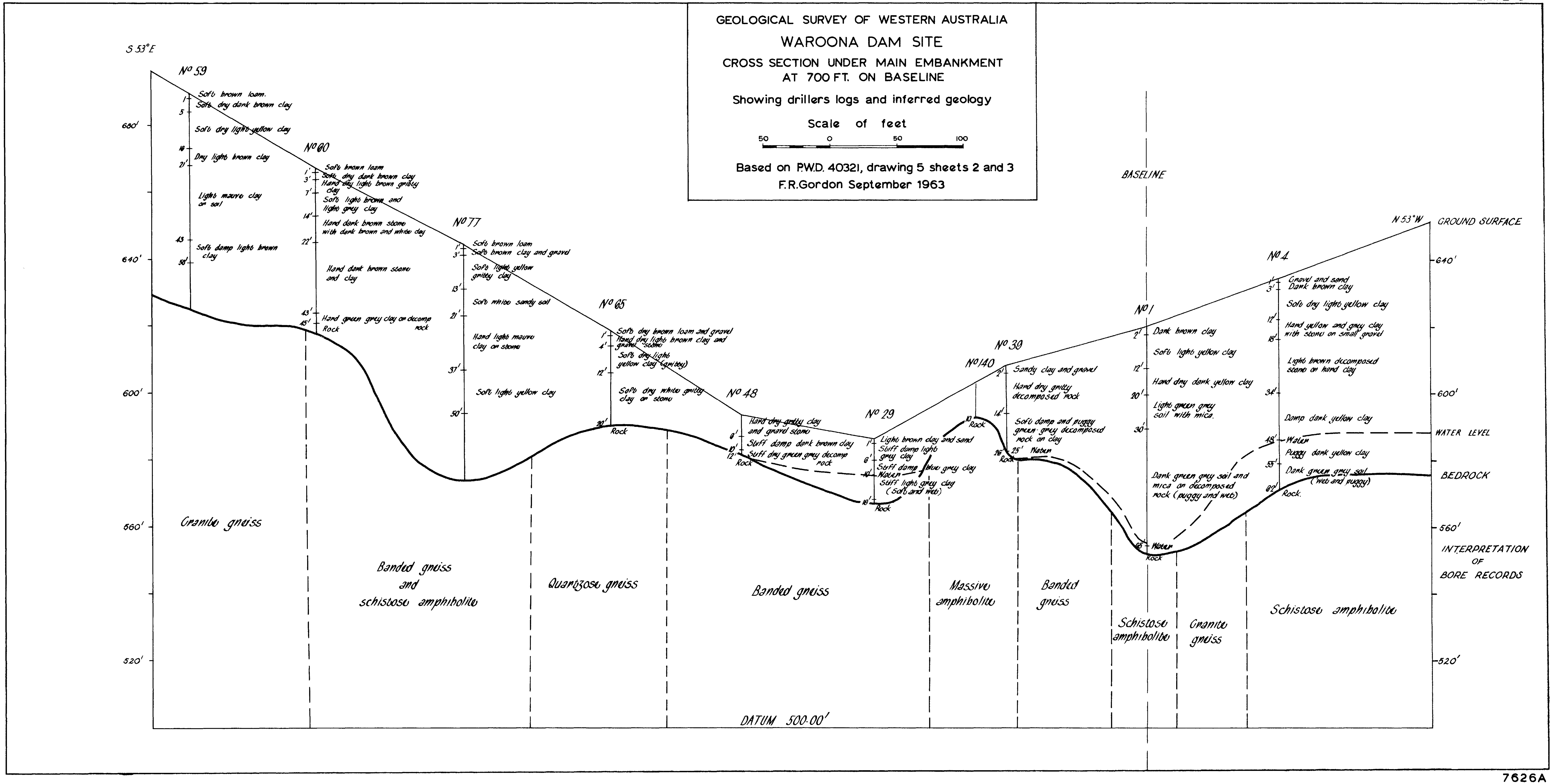
Depth	Drillers log	Geological equivalent
Feet		
0– 3	Soft dark brown clay	Laterite.
3–13	Hard light yellow clay or stone	Gibbsite phase weathering.
13–17	Soft light yellow and grey clay	Kaolin phase weathering (hydrous aluminium silicate minerals).
17–34	Hard light brown clay and stone	Kaolin phase weathering (more siliceous).
34–40	Hard green grey decomposed rock and clay	Weathered amphibolite band.
40–65	Soft dry dark brown soil	Sandy phase, quartzose.
65–80	Soft moist light brown and green grey soil with mica	Sandy phase, mica and quartz (permeable ?).
80–89	Stiff damp dark green grey rock and mica	Decomposed amphibolite (highly weathered).
89	Rock	Schistose amphibolite (slightly weathered).

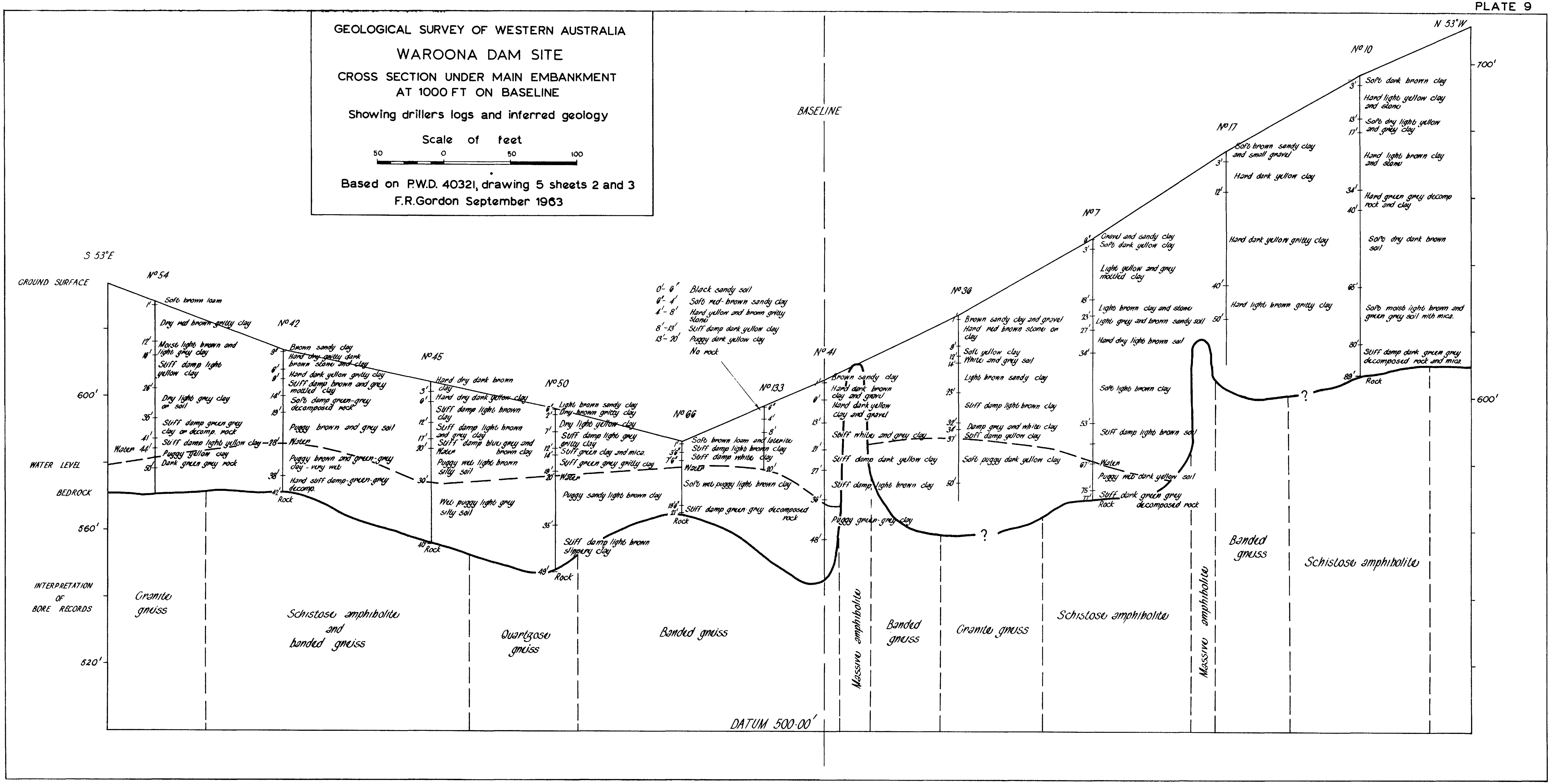
Banded gneiss is highly susceptible to weathering, and the major troughs in bedrock through the foundation area of the dam appear to be in this rock type. The tributary valley of noteworthy alignment in a north-northeast direction also appears to be eroded in banded gneiss. The rock is characteristically fine to medium grained, and shows both dark coloured (micaceous) and light coloured (quartzose) bands, these being often less than an inch thick.

Bore 155. Dam centre line 900 feet, and 95 feet left.

Depth	Drillers log	Geological equivalent
Feet		
0– 1	Black sandy soil	
1– 4	Light brown clays and laterite gravel	Laterite and gibbsite clay.
4– 8	Soft light yellow clay sandy and dry	Kaolin with limonite nodules.
8–14	Soft moist grey-green soil	Kaolin phase weathering.
14–18	Soft slippery green soil	Kaolin and sandy phases.
18–46	Soft grey green soil	18–24 ft., sandy phase, no clay.
24	Water	24–30 ft., ferruginated zone.
46	No rock	30–39 ft., permeable quartz. phase, no clay.
		39–45 ft., permeable quartz and mica phase.
		45 ft., highly decomposed banded gneiss.


LEGEND
Outcrop Amphibolite Granite
Inferred Geological boundary with lithology
AMPHIBOLITE
Gemco Auger Bore with PWD number and depth to rock (R) in feet (NR = No Rock)
Undisturbed sampling in auger bore
Lithology in boreholes and outcrops
Granite gneiss
Alluvials over bedrock
Quartzose gneiss
Banded gneiss
Amphibolite
Not available for Examination
GEOLOGICAL SURVEY OF WESTERN AUSTRALIA
WAROONA DAM SITE
INFERRED GEOLOGY
AND
LOCATION OF AUGER BORES
Scale in Feet
Based on PWD 40321, Drawing 1, Sheet 5
F R Gordon Sept 1963
N
SIDE CHANNEL SPILLWAY
SPILLWAY CHUTE
BANDED GNEISS
SCHISTOSE AMPHIBOLITE
GRANITE GNEISS
MASSIVE AMPHIBOLITE
UPSTREAM CONTROL TOWER LOCATION
OFFTAKE PIPE
CROSS SECTION LINE
G S CENTRELINE (NEW)
℄ OF TOP OF DAM (ORIGINAL)
BASELINE TRAVERSE
QUARTZOSE GNEISS
SCHISTOSE AMPHIBOLITE AND BANDED GNEISS
WATER FALL
EXFOLIATING BOSS OF GRANITE GNEISS
80° 31' 20"
7625


GEOLOGICAL SURVEY OF WESTERN AUSTRALIA
WAROONA DAM SITE
CROSS SECTION UNDER MAIN EMBANKMENT
AT 700 FT. ON BASELINE
Showing drillers logs and inferred geology
Scale of feet
50 0 50 100
Based on P.W.D. 40321, drawing 5 sheets 2 and 3
F.R.Gordon September 1963
S 53°E
N 53°W
GROUND SURFACE
BASELINE
WATER LEVEL
BEDROCK
INTERPRETATION OF BORE RECORDS
DATUM 500·00'
680'
640'
600'
560'
520'
No 59
Soft brown loam.
Soft dry dark brown clay
Soft dry light yellow clay
Dry light brown clay
Light mauve clay on soil
Soft damp light brown clay
No 60
Soft brown loam
Soft dry dark brown clay
Hard dry light brown gritty clay
Soft light brown and light grey clay
Hard dark brown stone with dark brown and white clay
Hard dark brown stone and clay
Hard green grey clay on decomp rock
Rock
No 77
Soft brown loam
Soft brown clay and gravel
Soft light yellow gritty clay
Soft white sandy soil
Hard light mauve clay on stone
Soft light yellow clay
No 65
Soft dry brown loam and gravel
Hard dry light brown clay and gravel stone
Soft dry light yellow clay (gritty)
Soft dry white gritty clay on stone
Rock
No 48
Hard dry gritty clay and gravel stone
Stiff damp dark brown clay
Stiff dry green grey decomp rock
Rock
No 29
Light brown clay and sand
Stiff damp light grey clay
Stiff damp blue grey clay
Water
Stiff light grey clay (Soft and wet)
Rock
No 140
Rock
No 39
Sandy clay and gravel
Hard dry gritty decomposed rock
Soft damp and puggy green-grey decomposed rock on clay
Water
Rock
No 1
Dark brown clay
Soft light yellow clay
Hard dry dark yellow clay
Light green grey soil with mica.
Dark green grey soil and mica on decomposed rock (puggy and wet)
Water
Rock
No 4
Gravel and sand
Dark brown clay
Soft dry light yellow clay
Hard yellow and grey clay with stone on small gravel
Light brown decomposed stone on hard clay
Damp dark yellow clay
Water
Puggy dark yellow clay
Dark green grey soil (wet and puggy)
Rock.
Granite gneiss
Banded gneiss and schistose amphibolite
Quartzose gneiss
Banded gneiss
Massive amphibolite
Banded gneiss
Schistose amphibolite
Granite gneiss
Schistose amphibolite


GEOLOGICAL SURVEY OF WESTERN AUSTRALIA
WAROONA DAM SITE
CROSS SECTION UNDER MAIN EMBANKMENT AT 1000 FT ON BASELINE
Showing drillers logs and inferred geology
Scale of feet
50 0 50 100
Based on P.W.D. 40321, drawing 5 sheets 2 and 3
F.R.Gordon September 1963
S 53°E
N 53°W
BASELINE
GROUND SURFACE
WATER LEVEL
BEDROCK
INTERPRETATION OF BORE RECORDS
DATUM 500·00'
700'
600'
560'
520'
No 54
Soft brown loam
Dry red brown gritty clay
Moist light brown and light grey clay
Stiff damp light yellow clay
Dry light grey clay or soil
Stiff damp green grey clay or decomp. rock
Stiff damp light yellow clay
Puggy yellow clay
Dark green grey rock
Water 44'
No 42
Brown sandy clay
Hard dry gritty dark brown stone and clay
Hard dark yellow gritty clay
Stiff damp brown and grey mottled clay
Soft damp green-grey decomposed rock
Puggy brown and grey soil
Water
Puggy brown and green-grey clay - very wet
Hard stiff damp green-grey decomp.
Rock
No 45
Hard dry dark brown clay
Hard dry dark yellow clay
Stiff damp light brown clay
Stiff damp light brown and grey clay
Stiff damp blue grey and brown clay
Water
Puggy wet light brown silty soil
Wet puggy light grey silty soil
Rock
No 50
Light brown sandy clay
Dry brown gritty clay
Dry light yellow clay
Stiff damp light grey gritty clay
Stiff green clay and mica.
Stiff green grey gritty clay
Water
Puggy sandy light brown clay
Stiff damp light brown slippery clay
Rock
No 66
Soft brown loam and laterite
Stiff damp light brown clay
Stiff damp white clay
Water
Soft wet puggy light brown clay
Stiff damp green grey decomposed rock
Rock
No 133
0'- 6" Black sandy soil
6"- 4' Soft red-brown sandy clay
4'- 8' Hard yellow and brown gritty stone
8'- 13' Stiff damp dark yellow clay
13'- 20' Puggy dark yellow clay
No rock
No 41
Brown sandy clay
Hard dark brown clay and gravel
Hard dark yellow clay and gravel
Stiff white and grey clay
Stiff damp dark yellow clay
Stiff damp light brown clay
Puggy green-grey clay
No 36
Brown sandy clay and gravel
Hard red brown stone on clay
Soft yellow clay
White and grey soil
Light brown sandy clay
Stiff damp light brown clay
Damp grey and white clay
Stiff damp yellow clay
Soft puggy dark yellow clay
No 7
Gravel and sandy clay
Soft dark yellow clay
Light yellow and grey mottled clay
Light brown clay and stone
Light grey and brown sandy soil
Hard dry light brown soil
Soft light brown clay
Stiff damp light brown soil
Water
Puggy wet dark yellow soil
Stiff dark green grey decomposed rock
Rock
No 17
Soft brown sandy clay and small gravel
Hard dark yellow clay
Hard dark yellow gritty clay
Hard light brown gritty clay
No 10
Soft dark brown clay
Hard light yellow clay and stone
Soft dry light yellow and grey clay
Hard light brown clay and stone
Hard green grey decomp rock and clay
Soft dry dark brown soil
Soft moist light brown and green grey soil with mica.
Stiff damp dark green grey decomposed rock and mica.
Rock
Granite gneiss
Schistose amphibolite and banded gneiss
Quartzose gneiss
Banded gneiss
Massive amphibolite
Banded gneiss
Granite gneiss
Schistose amphibolite
Massive amphibolite
Banded gneiss
Schistose amphibolite

Granite gneiss and quartzose gneiss are usually massive, and form pronounced ridges in the bedrock pattern due to relative resistance to weathering. A typical soil profile sequence is shown in bore 154, at 800 feet on centre line and 100 feet left:—

Depth	Drillers log	Geological equivalent
Feet		
0– ½	Soft light brown and black loam	Laterite-saprolite.
½– 2	Soft red brown clay and gravel	Gibbsitic laterite.
2–6	Soft light yellow clay with light brown gravel stone	Kaolin-gibbsite.
6–10½	Very soft deep yellow and whitish grey clay	Kaolin, some gibbsite, etc.
10½–13	Stiff whitish grey soapy clay	Kaolin phase weathering.
13–27	Soft whitish grey and light brown (clay or soil)	At 15 ft. ferruginated zone.
15	Water	At groundwater level.
27–35	Soft light brown stone or clay	Sandy-silty phase, quartzose.
35–36	Hard clay or damp green grey soil	Sandy phase, quartz and mica.
36–	Rock	Decomposed rock, quartzose gneiss.

The question of rock weathering has been emphasised in order to show the great variations both vertically and laterally that are possible over an area of weathered metasediments as are present at the Waroona dam site. The application of this work to the question of giving appropriate index properties to borrow pit material and to the method of borrowing is important, and is discussed separately.

However, the geological setting of the dam site is not a good one, with bands of altered sediments, in places deeply weathered, running through the foundation area.

DRILLING RESULTS

The drilling results obtained from bores in the foundation area of the dam show close attention to detail, and may be used as the basis for geological interpretation. Using the description of the weathered material above rock or the deepest observation in each hole, and assuming that amphibolite gives a grey-green coloured residual, fine grained banded gneiss a grey product, and quartzose gneiss a yellow weathering product, then an inferred distribution of rock types can be plotted (Plate 7).

Attempts to draw a structure contour map of the bedrock surface were not satisfactory because of the fact that many bores did not reach bedrock, but stopped at an arbitrary depth. Of the 13 bores shown on the cross section along the line of the original cut-off trench, only four reached solid rock, the rest being abandoned at 30 or 40 feet depth.

In order to check the auger drilling and provide some information on the nature of the bed rock, especially in the vicinity of the stream bed, some diamond drilling would be desirable. There is no assurance that sound rock extends under the valley floor on the cut-off line, and no knowledge of the nature of rock jointing in this area, apart from the fact that it probably runs through the site at right angles to the centre line.

SITE APPRAISAL

The bedrock at the Waroona dam site is formed largely of altered sedimentary rocks of considerable variety. They strike along the valley and thus transect the proposed earth-fill dam at right angles. Depending on the rock type and the type of weathering locally prominent, chemical and physical breakdown has produced a widely varying thickness of weathered mantle, ranging from slight weathering on surface outcrop to a sequence over 100 feet thick. In these deeply weathered profiles, certain zones are of high permeability, especially that between ground water level and slightly weathered rock.

Of special concern is the zone about 100 feet wide that intersects the proposed centre line between the 900 and 1,000 feet pegs.

With the construction of an earth-fill dam in the proposed position and the creation of considerable water pressure on the upstream valley floor, conditions are such that considerable leakage would take place underneath the embankment, to the extent of endangering the whole structure if special precautions were not taken. The construction of a cut-off wall down to slightly weathered rock and the provision of a relief well system would be essential. The high cost of a full cut-off wall makes it highly desirable to search for another location where subsurface conditions are more favourable.

In any assessment of conditions of foundations the following considerations are of importance:—

(1) The strike of the bands of metasediments is approximately 010 degrees, whereas Drakes Brook, and the main valley direction south of the proposed centre line, trends approximately 045 degrees. This means that south of the proposed centre line, the rock bands and weathering zones are running up hill. This is accentuated by a steepening of the valley slope on the southeast side, to the south of the proposed centre line.

(2) If a highly permeable band passes through the foundation area of the dam, it is better to have it high on the abutment rather than close to the stream, as water pressures from impounded water will be less.

(3) The ground water level following the more permeable layers appears to be nearly level in the vicinity of the stream but drops with increasing distance from the valley. This means that the badly weathered zone generally has a thicker cover remote from the middle of the valley.

(4) The contours show that the steepest part of the valley on the southeast side is on the line 700 feet on Base Line, and beyond the 600 feet line the valley widens. North of 900 feet on Base Line the valley also widens, and the tributary junction is approached. This means that any shift of the centre line is contained by definite limits. On the northwest bank, the layout of the spillway chute means it would be desirable to pivot the centre line about a fixed point on the west end.

(5) The cross section at 700 feet Base Line (Plate 8) shows no apparently pervious weathering zones resulting from a combination of factors 1 and 3 above. Bedrock was encountered in all bores except No. 77, which indicates that if a cut-off wall was necessary in this vicinity, it would be of lesser depth than one on the proposed cut-off line.

(6) Borings on the 600 feet cross section off Base Line show poor material at 600 and 700 feet right, i.e., high in the abutment.

These factors indicate that it would be advantageous to move the centre line as far as possible downstream (on southwards) on the southeast abutment. Pivoting on the northwest end, the southeast end of the centre line may be moved to 600 feet on Base Line, and this means that the cut-off trench will be close to the favourable material on the 700 feet Base Line, in the critical area where the deeply weathered schistose amphibolite and banded gneiss bands pass.

Further boring on the new cut-off line is necessary, and the results of this must govern future judgments as to the necessity for a complete wall. It is suggested that in the event of pervious zones being encountered on the new line, a field permeability test should be carried out. (U.S. Bureau of Reclamation E 18 or E 19.)

There are constructional difficulties imposed by the bedrock topography, in particular by the outcropping bands of massive amphibolite (Plates 8, 9). These apparently form almost vertical ridges and the result is that placement by hand of the fill material will be necessary, along with the use of wetter than optimum material in order to secure adequate bond with the rock. A further problem is set by the possibility of differential settlement between portions of the core wall founded on ridges of solid rock and, immediately adjacent, founded on a weathered rock sequence over 50 feet thick. The possibility of shearing through the core wall must be evaluated in the light of soil mechanics tests of the compressibility of the clays under the dam loading. It is considered that the amphibolite ridges should be removed where exposed in the foundation area of the dam. The rock will be useful as riprap.

A silty, grey-brown clay, highly micaceous, and quite puggy when wet, is found in the valley bottom, and is probably alluvial. As solid rock is usually within 10 to 15 feet of the surface, this undesirable material should be removed from the foundation area of the dam. This would be over a width of 100 feet in the widest part of the valley floor, i.e., about 850 feet on Base Line.

BORROW MATERIAL

No samples have been geologically examined from either of the proposed borrow areas, but sufficient data are available from the dam area to show the trends to be expected.

There will be a great variation vertically from soil surface to rock, and in the weathered rock the permeability will vary widely, usually increasing with depth. This means that in order to obtain representative values for index properties, each type of soil should be weighted by its thickness.

The following considerations have been found valid:—

(i) Increasing mica content (towards the bottom of the borrow sequence) means a reduction in liquid limit and an increase in plastic limit.

(ii) Increasing quartz grit content (middle of the borrow sequence) means a reduction in liquid limit while the plastic limit remains constant.

The banded nature of the gneissic rock means that rapid lateral variations of soil type must be expected over a borrow area.

In order to obtain a homogeneous product these facts must be considered in laying out the stripping programme for a borrow pit. For example, if the soil type were all derived from granite gneiss, then working the borrow area in slices parallel to the surface would produce an impervious kaolin clay from the top 15 feet say, followed by a permeable quartzose sandy soil from the next 10 feet. This indicates the necessity for inclined slices in excavating—across the area. However, the alteration produced by the presence of different rock types, including the presence of ridges of outcropping massive amphibolite in the south borrow pit must be considered.

The soils of high mica content tend to alter considerably on reworking, and for laboratory testing, fresh material should be used for each test in a series, e.g., Proctor compaction testing. In construction procedure the method of placement should involve as little handling as possible.

CONCLUSIONS

1. The foundation area of the Waroona dam site has been investigated by extensive auger boring. Sampling on the line of the proposed cut-off trench revealed zones of highly permeable material.

2. Geological examination of the cores revealed great vertical differences in weathering products, and lateral variation in rock types.

3. A brief mapping programme showed the presence of banded gneissic rocks transecting the foundation area of the dam. From geological considerations a downstream shift of the dam centre line was recommended, involving a maximum displacement of 170 feet.

4. The continuity of the bedrock and the possibility of potential leakage paths in bedrock is not demonstrable as no diamond drilling has been carried out.

5. Foundation design must consider bands of soft altered soil, existing in close proximity with ridges of hard unweathered rock. This will have a complicating effect on bearing capacity and settlement computations. This must be considered especially on the north bank where two narrow ridges of massive amphibolite crop out adjacent to weathered sequences of over 50 feet in depth. As the ridges run through the structure, any consolidation of the weathered soils would tend to produce shear planes through the earth fill and core wall.

Care must be taken to secure an adequate bond between the rock ridges and the core material, and this will involve hand placement and variations in moisture content of the core material. It is recommended that these rock ridges should be removed in the foundation area.

6. The micaceous nature of some of the local soils will introduce constructional difficulties, especially if considerable handling is involved as this will tend to alter the soil properties.

7. Vertical and lateral variations of soil in the borrow area make it desirable to have complete control of the stripping programme to allow production of a homogeneous product.

8. The soft, puggy silty clay in the valley bottom is an undesirable material, and should be removed in the foundation area of the dam. Bedrock is usually close to the surface, and the width involved is small.

ENGINEERING GEOLOGY REPORT ON A PROPOSED DAM SITE ON THE SOUTH CANNING RIVER

By J. D. Wyatt

ABSTRACT

During 1963 a detailed examination of a proposed dam site on the South Canning River was carried out by the Geological Survey of W.A.

Geological mapping on a scale of 100 feet to one inch together with two diamond drill holes 153 feet and 250 feet long respectively, revealed a complex dolerite dyke system which showed no evidence of major faulting.

Dolerite dyke emplacement along major joint sets have controlled river channel direction.

Water seepage through the foundation area would be restricted to the dolerite dykes which will require remedial grouting.

INTRODUCTION

A dam, to augment storage in the Canning Reservoir, is proposed on the South Canning River, some ¾ mile north-northeast of Eagle Hill trig. station, lying within Government Reserve 5913, as shown on Lands and Surveys Lithograph 341C/40.

Following a preliminary investigation by the Metropolitan Water Supply Department a more detailed geological and geophysical survey of the site was made which resulted in the recommendation that two diamond drill holes be constructed.

This report sets out the results of the detailed geological mapping and diamond drilling, and contains comments on the suitability of the site.

TOPOGRAPHY AND DRAINAGE

The overall topography is rough with a considerable amount of rock outcrop. Prominent boulder strewn ridges usually mark the approximate positions of the larger dolerite dykes, whilst extensive, gently-dipping exfoliation slopes together with jumbled masses of boulders are typical of the granite-gneiss outcrops.

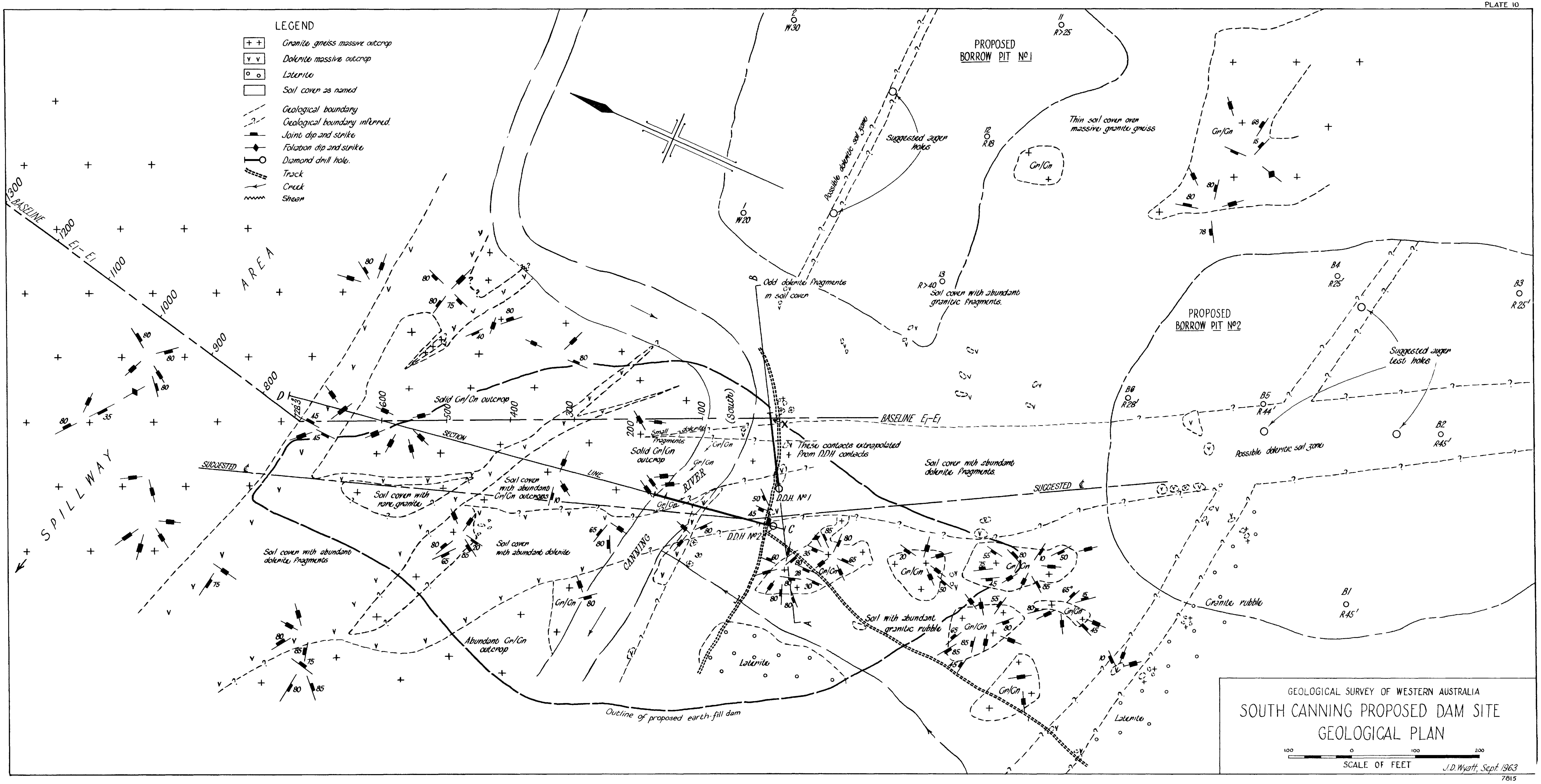
Drainage into the South Canning River is restricted to short, intermittent creeks which originate as surface runoff from the adjacent hill slopes and as springs issuing from exfoliation joints, extensively fissured dolerites, and the base of the laterite cover.

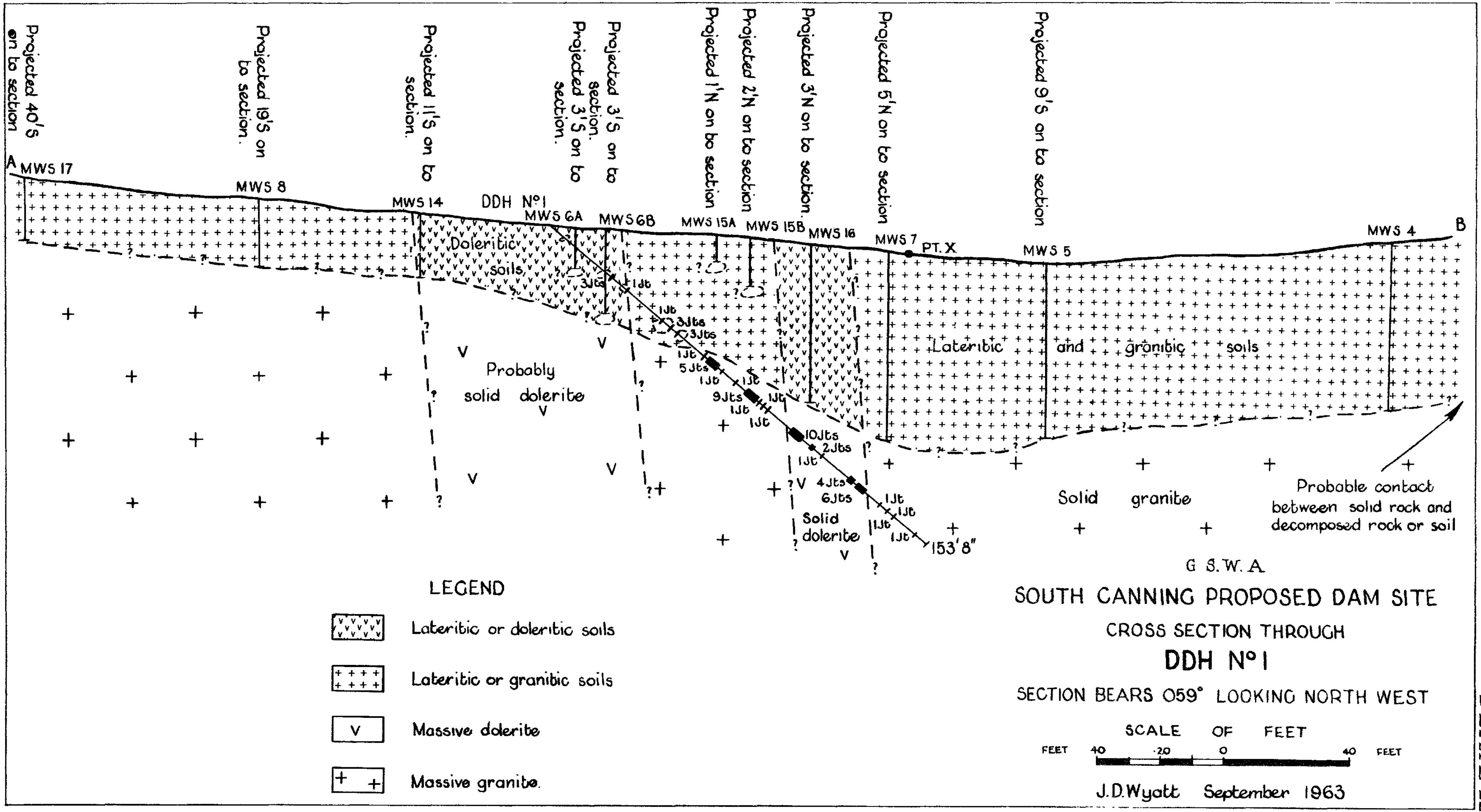
GEOLOGY

The general geology comprises an igneous complex of foliated granite-gneisses intruded by numerous dolerite dykes.

These rock types are locally deeply-weathered to lateritic clay and sandy soils, with small deposits of alluvial sands along the river.

High on the valley slopes above about the 850 feet contour line, are outcrops of massive and pisolitic laterite.


LEGEND
Granite gneiss massive outcrop
Dolerite massive outcrop
Laterite
Soil cover as named
Geological boundary
Geological boundary inferred.
Joint dip and strike
Foliation dip and strike
Diamond drill hole.
Track
Creek
Shear
PROPOSED BORROW PIT No 1
PROPOSED BORROW PIT No 2
Thin soil cover over massive granite gneiss
Suggested auger holes
Suggested auger test holes
Possible doleritic soil zone
Odd dolerite fragments in soil cover
Soil cover with abundant granitic fragments.
Soil cover with abundant dolerite fragments.
BASELINE E1-E1
SUGGESTED ℄
SECTION LINE
SPILLWAY AREA
Solid Gn/Gn outcrop
Soil cover with rare granite
Soil cover with abundant Gr/Gn outcrops
Soil cover with abundant dolerite
Soil cover with abundant dolerite fragments
These contacts extrapolated from D.D.H. contacts
D.D.H. No 1
D.D.H. No 2
CANNING RIVER
(South)
Small dolerite fragments
Abundant Gr/Gn outcrop
Soil with abundant granitic rubble
Granite rubble
Laterite
Outline of proposed earth-fill dam
GEOLOGICAL SURVEY OF WESTERN AUSTRALIA
SOUTH CANNING PROPOSED DAM SITE
GEOLOGICAL PLAN
SCALE OF FEET
J.D. Wyatt, Sept. 1963
7815



G S.W. A

SOUTH CANNING PROPOSED DAM SITE

CROSS SECTION THROUGH

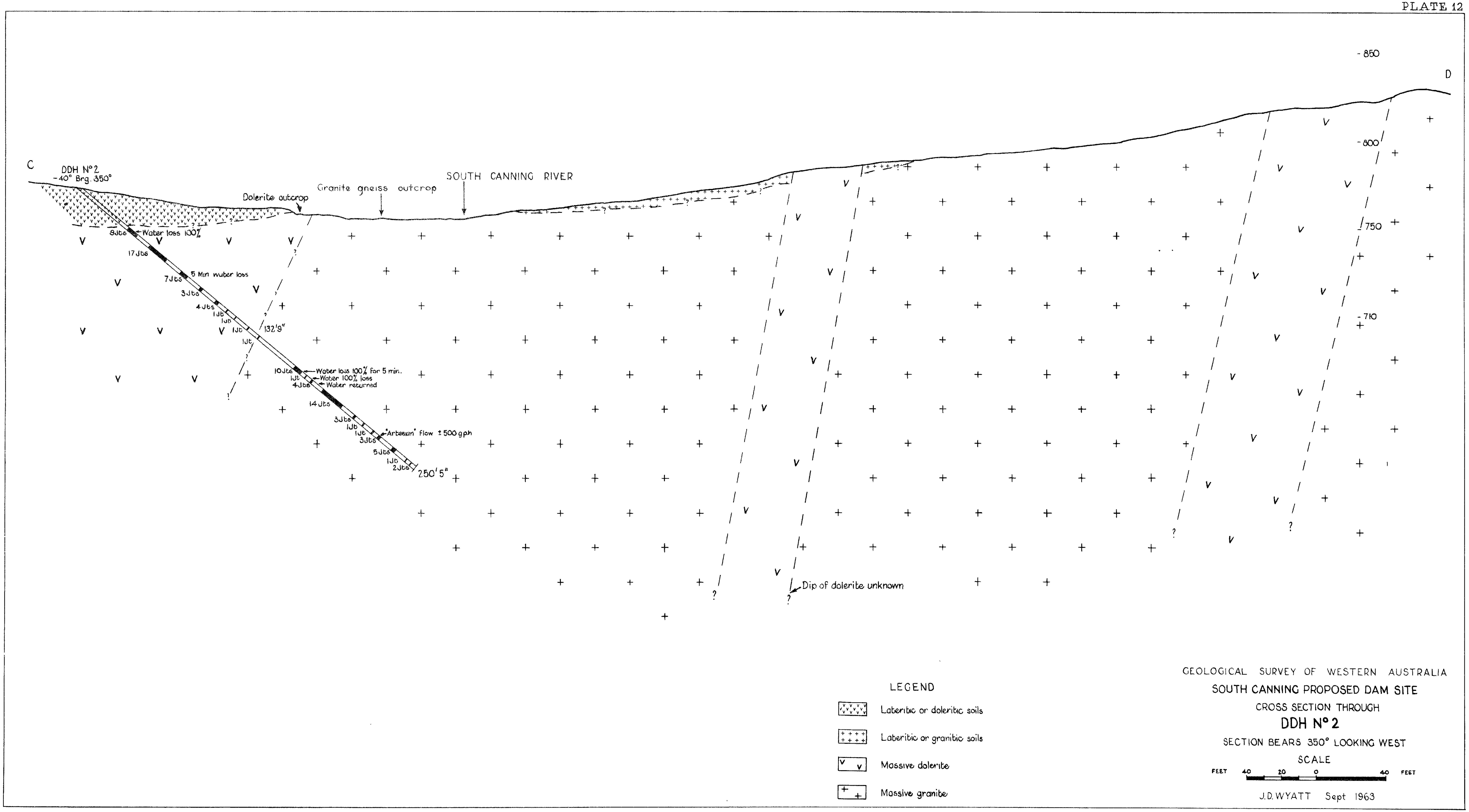
DDH N°1

SECTION BEARS 059° LOOKING NORTH WEST

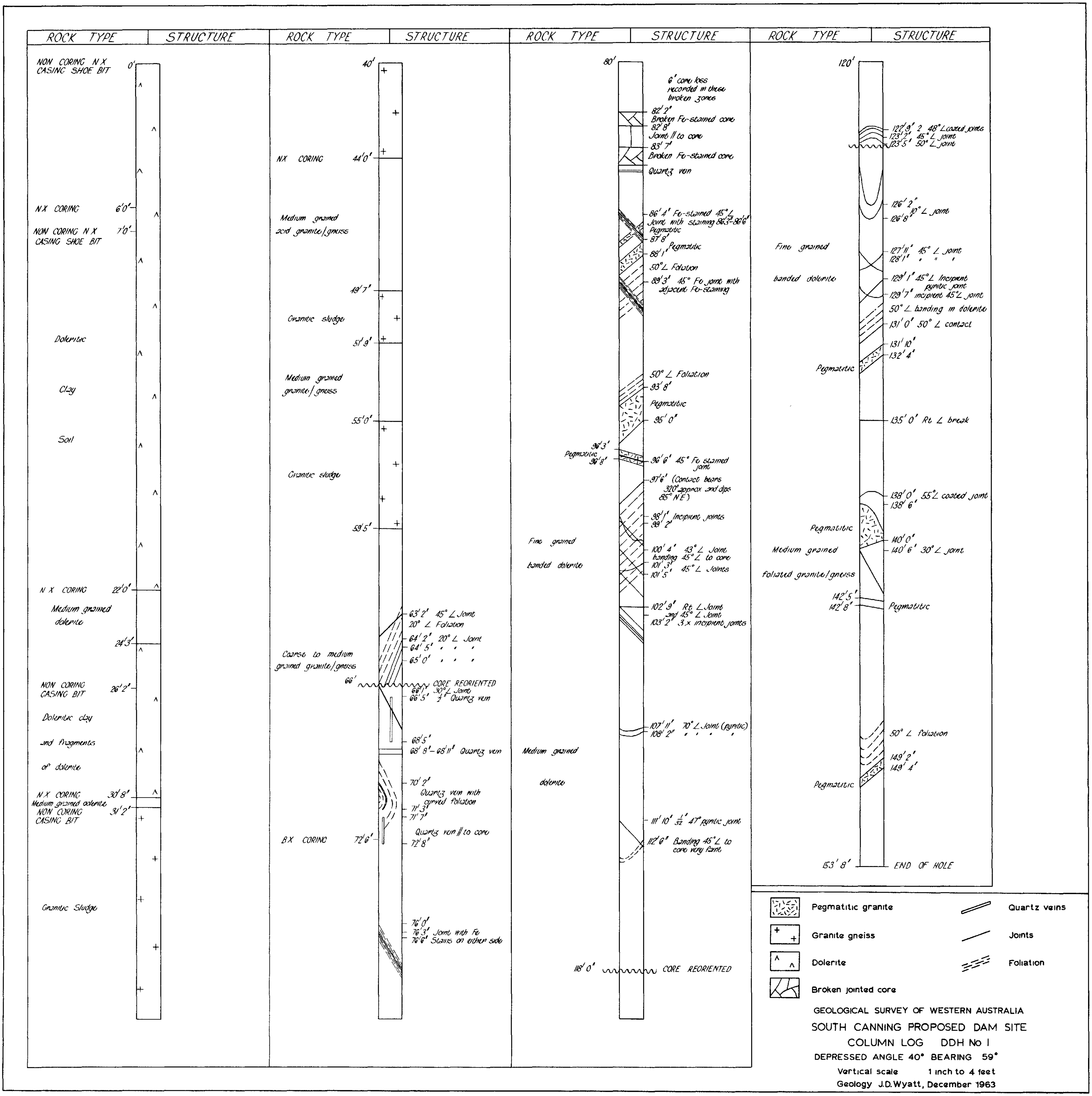
J.D.Wyatt September 1963

PLATE 11

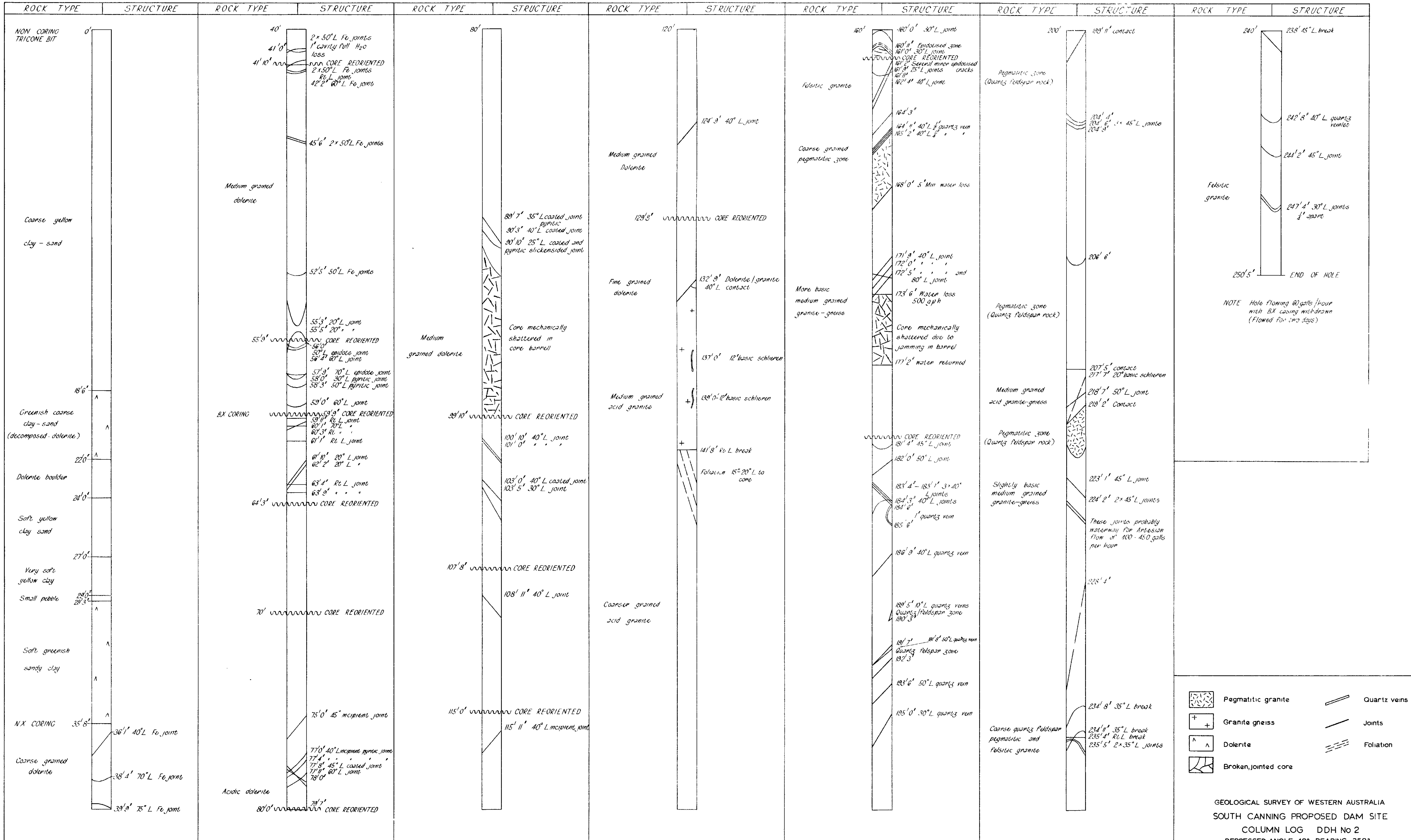
7816


C
DDH Nº 2
-40° Brg. 350°
D
- 850
- 800
750
- 710
Dolerite outcrop
Granite gneiss outcrop
SOUTH CANNING RIVER
8Jts Water loss 100%
17Jts
7Jts 5 Min water loss
3Jts
4Jts
1Jt
1Jt
1Jt
1Jt
132'9"
10Jts Water loss 100% for 5 min.
1Jt Water 100% loss
4Jts Water returned
14Jts
3Jts
1Jt
1Jt "Artesian" flow ± 500 gph
3Jts
5Jts
1Jt
2Jts
250'5"
Dip of dolerite unknown
LEGEND
Lateritic or doleritic soils
Lateritic or granitic soils
Massive dolerite
Massive granite
GEOLOGICAL SURVEY OF WESTERN AUSTRALIA
SOUTH CANNING PROPOSED DAM SITE
CROSS SECTION THROUGH
DDH Nº 2
SECTION BEARS 350° LOOKING WEST
SCALE
FEET 40 20 0 40 FEET
J.D. WYATT Sept 1963

7817


ROCK TYPE
STRUCTURE
NON CORING N X CASING SHOE BIT
0'
N X CORING 6'0"
NON CORING N X CASING SHOE BIT 7'0"
Doleritic
Clay
Soil
N X CORING 22'0"
Medium grained dolerite
24'3"
NON CORING CASING BIT 26'2"
Doleritic clay and fragments of dolerite
N X CORING 30'8"
Medium grained dolerite
NON CORING CASING BIT 31'2"
Granitic Sludge
40'
NX CORING 44'0"
Medium grained acid granite/gneiss
49'7"
Granitic sludge
51'9"
Medium grained granite/gneiss
55'0"
Granitic sludge
59'5"
63'2" 45° ∠ Joint
20° ∠ Foliation
64'2" 20° ∠ Joint
64'5"
65'0"
Coarse to medium grained granite/gneiss
66'
CORE REORIENTED
66'1" 30° ∠ Joint
66'5" ½" Quartz vein
68'5"
68'8" – 68'11" Quartz vein
70'2"
Quartz vein with curved foliation
71'3"
71'7"
Quartz vein // to core
BX CORING 72'6"
72'8"
76'0"
76'3" Joint with Fe
76'6" Stains on either side
80'
6" core loss recorded in these broken zones
82'2"
Broken Fe-stained core
82'8"
Joint // to core
83'7"
Broken Fe-stained core
Quartz vein
86'4" Fe-stained 45° ∠ Joint with staining 86'3"-86'6"
Pegmatitic
87'8"
88'1" Pegmatitic
50° ∠ Foliation
89'3" 45° Fe joint with adjacent Fe-staining
50° ∠ Foliation
93'8"
Pegmatitic
95'0"
96'3"
Pegmatitic
96'8"
96'6" 45° Fe stained joint
97'6" (Contact bears 320° approx and dips 85° NE)
98'1" Incipient joints
99'2"
Fine grained banded dolerite
100'4" 43° ∠ Joint banding 45° ∠ to core
101'3" 45° ∠ Joints
101'5"
102'9" Rt ∠ Joint and 45° ∠ Joint
103'2" 3 x incipient joints
107'11" 70° ∠ Joint (pyritic)
108'2"
Medium grained dolerite
111'10" 1/32" 47° pyritic joint
112'6" Banding 45° ∠ to core very faint
118'0"
CORE REORIENTED
120'
122'9" 2 48° ∠ coated joints
123'2" 45° ∠ joint
123'5" 50° ∠ joint
126'2"
10° ∠ joint
126'8"
Fine grained banded dolerite
127'11" 45° ∠ joint
128'1"
129'1" 45° ∠ Incipient pyritic joint
129'7" incipient 45° ∠ joint
50° ∠ banding in dolerite
131'0" 50° ∠ contact
131'10"
132'4"
Pegmatitic
135'0" Rt ∠ break
138'0" 55° ∠ coated joint
138'6"
Pegmatitic
140'0"
140'6" 30° ∠ joint
Medium grained foliated granite/gneiss
142'5"
142'8"
Pegmatitic
50° ∠ foliation
149'2"
149'4"
Pegmatitic
153'8"
END OF HOLE
Pegmatitic granite
Granite gneiss
Dolerite
Broken jointed core
Quartz veins
Joints
Foliation
GEOLOGICAL SURVEY OF WESTERN AUSTRALIA
SOUTH CANNING PROPOSED DAM SITE
COLUMN LOG DDH No 1
DEPRESSED ANGLE 40° BEARING 59°
Vertical scale 1 inch to 4 feet
Geology J.D.Wyatt, December 1963

7897



GEOLOGICAL SURVEY OF WESTERN AUSTRALIA

SOUTH CANNING PROPOSED DAM SITE

COLUMN LOG DDH No 2

DEPRESSED ANGLE 40° BEARING 350°

Vertical scale 1 inch to 4 feet

Geology J D Wyatt, December 1963

7898

North Abutment

The northern valley slope is characterised by an abundant rock outcrop, together with a thin soil cover.

In the proposed foundation area a complex dolerite dyke system striking roughly northwest intrudes granite-gneiss, whilst most of the spillway will be sited on bare, massive, gently-dipping granite-gneiss.

South Abutment

Geologically the southern valley slope is rather more obscure, the same igneous rock types being present but with outcrops less abundant. There is also a thick mantle of weathered soil and laterite which covers some 70 per cent. of the proposed abutment.

Dolerite dyke outcrop and boulder rubble, striking north-northwest occupies the central part of the slope with soil cover obscuring much of the geology to the east.

Along the western contact of this central dyke large masses of granite-gneiss boulders crop out with an intervening soil mantle.

Two smaller dykes which strike almost due west are most likely offshoots from the central dyke system. One of these smaller dykes crops out along the southern bank of the South Canning River and the second crops out higher on the valley slope some 200 feet south of the proposed dam wall (see Plate 10).

Surface rubble suggests the existence of a third parallel dyke midway between the above two dolerite dykes.

JOINTING

From the numerous joint readings taken over the abutment area and from an examination of the diamond drill cores several important facts emerge:—

(1) Both the dolerite dykes and granite-gneiss have a characteristic set of major joint planes and the frequency of these joint planes is greater for the dolerite dykes than the granite gneiss in the decomposed surface zone.

(2) Jointing planes observed in diamond drill holes become less frequent with depth but are still capable of carrying water at drill depths down to 173 feet.

(3) Continuous jointing is common to both dolerite and the exfoliation type granite-gneiss, resulting in connected seepage paths covering distances of at least 150 feet.

(4) The most important joint in the granite-gneiss is a flat-lying exfoliation joint which is probably responsible for water losses in the shallower sections of the diamond drill holes.

The conclusions which may be drawn from the above facts are as follows:—

Firstly, any dolerite dyke which lies within the proposed foundation area and strikes at an angle through the centre line of the dam is a potential source of seepage and will require remedial treatment during construction. The dolerite dyke which is aligned parallel to the southern bank of the river some 100 feet north of D.D.H. No. 2 strikes almost at right angles to the axis of the proposed dam, and must be considered a potential seepage path (see Plate 10).

Secondly, the continuous, steeply-dipping, major joint sets noted in the exfoliation type granite-gneiss outcrops are worthy of consideration. In themselves they will not promote leakage under the wall, but they do intersect the flat lying exfoliation joints which carry water, and will therefore leak into the cutoff channel.

They will, therefore, have to be sealed by grouting during the construction of a cutoff channel.

DRILLING

Investigation drilling of the dam site was carried out in two stages:—

(1) Auger drilling completed by the Metropolitan Water Supply Department, to provide information on two potential borrow pit areas and to test the depth of soil cover on the proposed southern abutment.

(2) Diamond drilling by the Mines Department to explore the rock types in the vicinity of the proposed centre line.

The auger drilling revealed a thick cover of soil which extended laterally over a large part of the southern valley slope and which became deeper from west to east, having a maximum thickness of 55 feet in the vicinity of Point X (see Plate 11). Geophysical and diamond drilling investigations confirmed this thickening, which is interpreted as a weathering phenomenon rather than a fault step.

Diamond drillhole No. 1 showed that the central dyke of the southern slope was not a single body but consisted of two dykes separated by a 500 feet wedge or strip of granite-gneiss (see Plates 11, 13).

As surface mapping did not reveal the presence of this granite-gneiss between the dolerite dykes, the siting of D.D.H. No. 1 meant it was still in decomposed material when it intersected the western contact between the dolerite and gneiss, so that the nature of this contact where unaltered is still unknown. However, the eastern contact was unsheared and apparently tight.

D.D.H. No. 2 again showed that the contact between the dolerite and the gneiss was watertight and not obviously faulted, but that open joint planes existed as deep as 224 feet drillhole depth (see Plates 12, 14).

BORROW PIT AREAS

Two borrow pit areas have been selected by the Metropolitan Water Supply Department, based on the drilling of 12 auger holes.

Both pits are situated on the southern valley slope on the upstream side of the proposed dam (see Plate 10).

Borrow Pit No. 1

A short surface examination of this borrow area together with the results of the diamond drilling suggests that dolerite clay soils will be encountered in a 20 to 30 feet wide strip running east-west across the centre of the proposed pit (see Plate 10). This clay band represents the extension of the dolerite dyke mapped along the southern bank of the South Canning River and which disappears to the eastward under a soil and vegetation cover.

It is suggested that some additional auger drilling could be done under geological supervision in order to establish whether the dyke does in fact extend this far east. Suggested sites are shown on Plate 10.

All other evidence indicates a homogeneous borrow material of pisolitic laterite and weathered granitic soils.

Borrow Pit No. 2

Surface mapping of occasional dolerite boulders within the borrow area indicates that dolerite clay soils may be encountered in a strip up to 100 feet wide running both through the area and across its northern end. These zones represent the extension of an east-west dyke and the main N 20° W trending dolerite system. If clay soils are encountered in these areas then a mixing of the soils may be necessary from different portions of the borrow areas. An alternative would be to avoid the zones and extend the borrow pits either west or south.

CONCLUSIONS AND RECOMMENDATIONS

1. The proposed South Canning dam site is located in an area of granite gneisses which have been intruded by an extensive dolerite dyke system having two main components.

   (i) An east-west trending system.

   (ii) A N 20° W to N 30° W trending system.

These dykes appear to be intruded along major joint plane directions.

2. The joint frequency in the granite gneisses is usually less than in the dolerites but a few major, continuous, open joints in both rock types act as seepage paths for water. The east-west dolerite dyke system, components of which will extend under the proposed dam, is particularly important in this respect.

3. The two valley slopes differ appreciably with regard to the areal extent and depth of soil cover.

The southern slope is generally deeply weathered up to a maximum depth of 57 feet and with the soil cover increasing to the east, whilst the northern slope is mainly rock outcrop and has only a thin soil cover.

4. Suspected faulting along the various dyke contacts has been largely discounted and there is no evidence to suggest a major fault plane parallel to the river under the proposed dam.

5. Diamond drilling has shown the foundation rock to be particularly sound, but the joint planes which were intersected are capable of carrying water. Grouting will be needed during the construction of a cutoff wall.

6. Both borrow pit areas appear to contain adequate quantities of suitable earth fill material, but additional auger drilling is needed if suspected dolerite dykes are to be outlined.

7. On the basis of diamond and auger drilling results it is recommended that the dam centre line be sited no further east than shown on Plate 10.

This positioning is controlled by three facts:—

   (i) The deeply decomposed zone in the vicinity Point X as shown on Plate 10.

   (ii) The central southern valley slope dolerite dyke system.

   (iii) The slope of the natural surface along the western margin of the abutment area, together with the small creek which drains into the South Canning in this vicinity.

An examination of the detailed geological and geophysical investigation results shows that no serious defects are evident which would preclude the building of an earth fill dam on the proposed site.

Care will be needed on the choice of a dam centre line, which should be placed considerably further downstream than the present pegged survey base line.

Adequate provision must be made for grouting beneath the foundation area, especially in the vicinity of the east-west trending dolerite dykes.

Allowance must also be made for the possible settlement of the deep soil cover in the vicinity of Point X, datum point of the pegged base line.

THE SEARCH FOR OIL IN WESTERN AUSTRALIA IN 1963

By P. E. Playford

During 1963 the rate of oil exploration in Western Australia continued to accelerate, though the number of exploratory wells drilled was less than for 1962. The over-all acceleration was associated with considerably increased geophysical activity in the State's sedimentary basins.

During the year one dry oil-test and two stratigraphic holes were completed in the Carnarvon Basin and one dry oil-test and one stratigraphic hole were completed in the Perth Basin. At the end of the year two oil-test wells were still drilling in the Carnarvon Basin and another was suspended for the duration of the wet season in the Bonaparte Gulf Basin.

Geophysical operations totalling some 52 party-months of seismic work, 44 party-months of gravity work, and a half-month of aeromagnetic work were conducted in the Perth, Carnarvon, Canning, Bonaparte Gulf, and Officer Basins. Surface geological mapping was undertaken by West Australian Petroleum Pty. Ltd. (Wapet) in the Canning Basin, by Hunt Oil Co. in the Officer Basin, and by the Geological Survey of Western Australia in the Perth and Canning Basins.

OIL HOLDINGS

The positions of Permits to Explore and Licenses to Prospect current in Western Australia at the end of 1963 are shown on Plate 15. Details regarding each permit and license are shown on the following table:—

OIL HOLDINGS IN WESTERN AUSTRALIA ON 31st DECEMBER, 1963

Permits to Explore.

No.	Name of Holder	Area in Square Miles	Date of Expiry of Current Tenure
27H	West Australian Petroleum Pty. Ltd.	52,000	31/12/64
28H	do. do. do.	51,000	31/12/64
30H	do. do. do.	151,600	31/12/64
106H	Westralian Oil Ltd.	11,800	28/9/63
127H	Alliance Oil Development Australia N.L.	13,800	28/3/64
134H	Exoil Pty. Ltd. & Hunt Petroleum Corporat ion	12,600	9/12/63
135H	do. do. do.	12,600	9/12/63
136H	do. do. do.	12,450	9/12/63
142H	Hawkstone Oil Co. Ltd.	5,200	8/4/64
147H	Hunt Oil Co. & Placid Oil Co.	12,850	16/8/64
148H	do. do. do.	12,600	16/8/64
151H	Hackathorn Oils Pty. Ltd.	14,200	7/2/64
152H	do. do.	11,650	7/2/64
153H	do. do.	13,050	7/2/64
156H	Hunt Oil Co. & Placid Oil Co.	12,450	10/7/64
157H	do. do. do.	12,600	10/7/64
158H	do. do. do.	12,800	10/7/64
159H	do. do. do.	12,800	10/7/64
161H	do. do. do.	12,900	24/8/64
165H	Vickers, Victor Ivor	13,700	19/12/63
166H	do. do.	5,315	19/12/63
167H	do. do.	13,550	27/12/63
171H	Turnbull, James	8,050	2/8/64
172H	Alliance Petroleum Australia N.L.	6,150	30/7/64
173H	do. do. do.	12,250	30/7/64
174H	do. do. do.	6,100	30/7/64
175H	do. do. do.	6,000	30/7/64
177H	do. do. do.	6,050	30/7/64
178H	Australian Oil Corporation	12,300	29/8/64
193H	Hawkstone Oil Co. Ltd.	2,700	5/8/64
199H	Pilbara Exploration N.L.	11,950	15/8/64
203H	Australian Oil Corporation	18,000	29/8/64
205H	Alliance Petroleum Australia N.L.	16,700	2/11/64
206H	do. do. do.	12,950	2/11/64
207H	do. do. do.	13,000	2/11/64
209H	Australian Oil Corporation	12,200	29/8/64
210H	do. do.	12,050	29/8/64
211H	do. do.	5,975	29/8/64
213H	Woodside (Lakes Entrance) Oil Co. N.L.	104,000	20/6/65
214H	Mitchell, Albert Edward....	6,000	Applied for
216H	Pilbara Exploration N.L.	13,200	10/4/65
217H	West Australian Petroleum Pty.Ltd.	17,600	30/5/65
220H	Planet Exploration Pty. Ltd.	13,850	Application pending
221H	Australian Aquitaine Petroleum Pty. Ltd.	60,000	do.
222H	Arco Ltd.	70,600	do.
223H	Shell Development (Aust.) Pty. Ltd.	8,017	do.
224H	do. do. do.	1,501	do.
225H	West Australian Petroleum Pty. Ltd.	7,500	do.

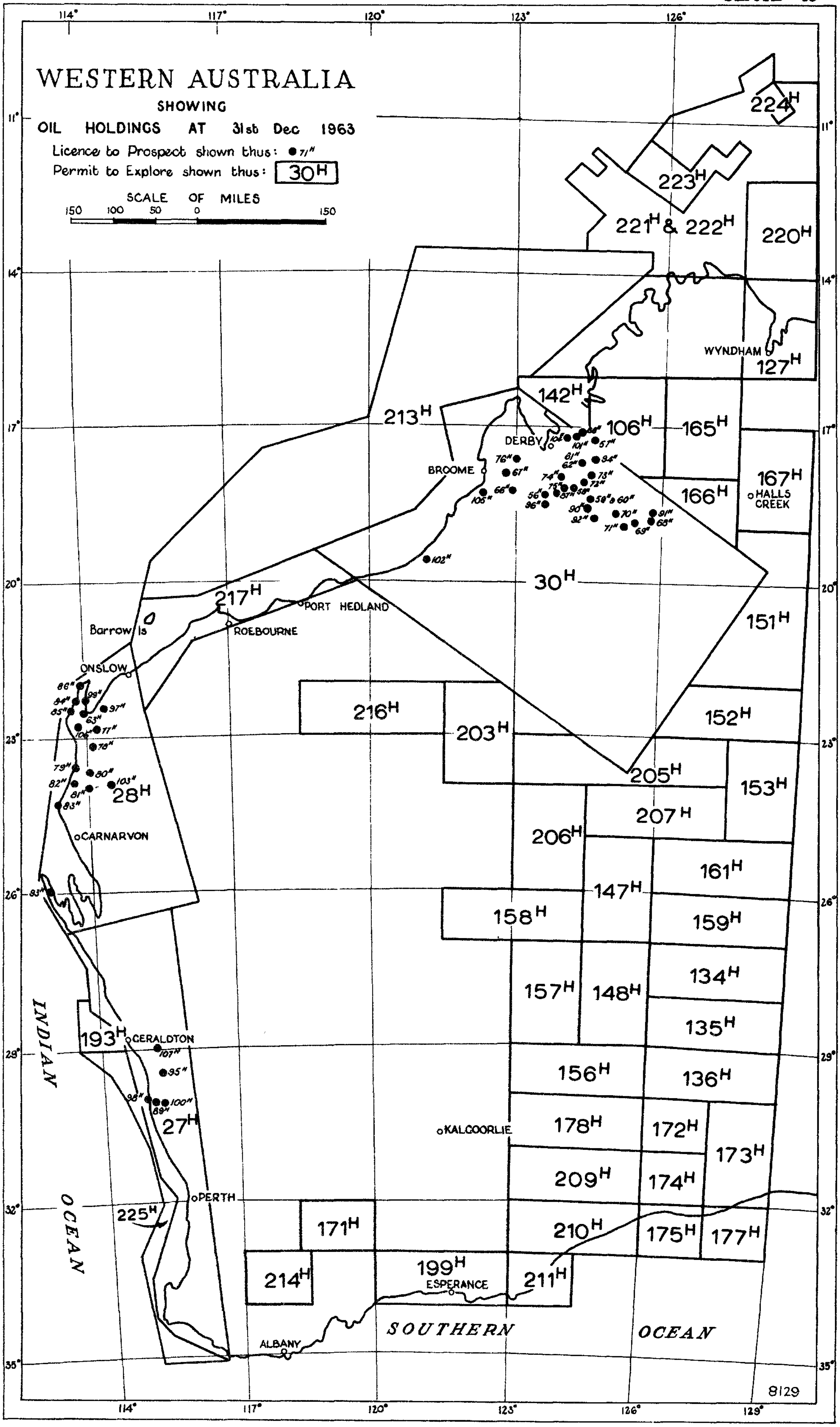
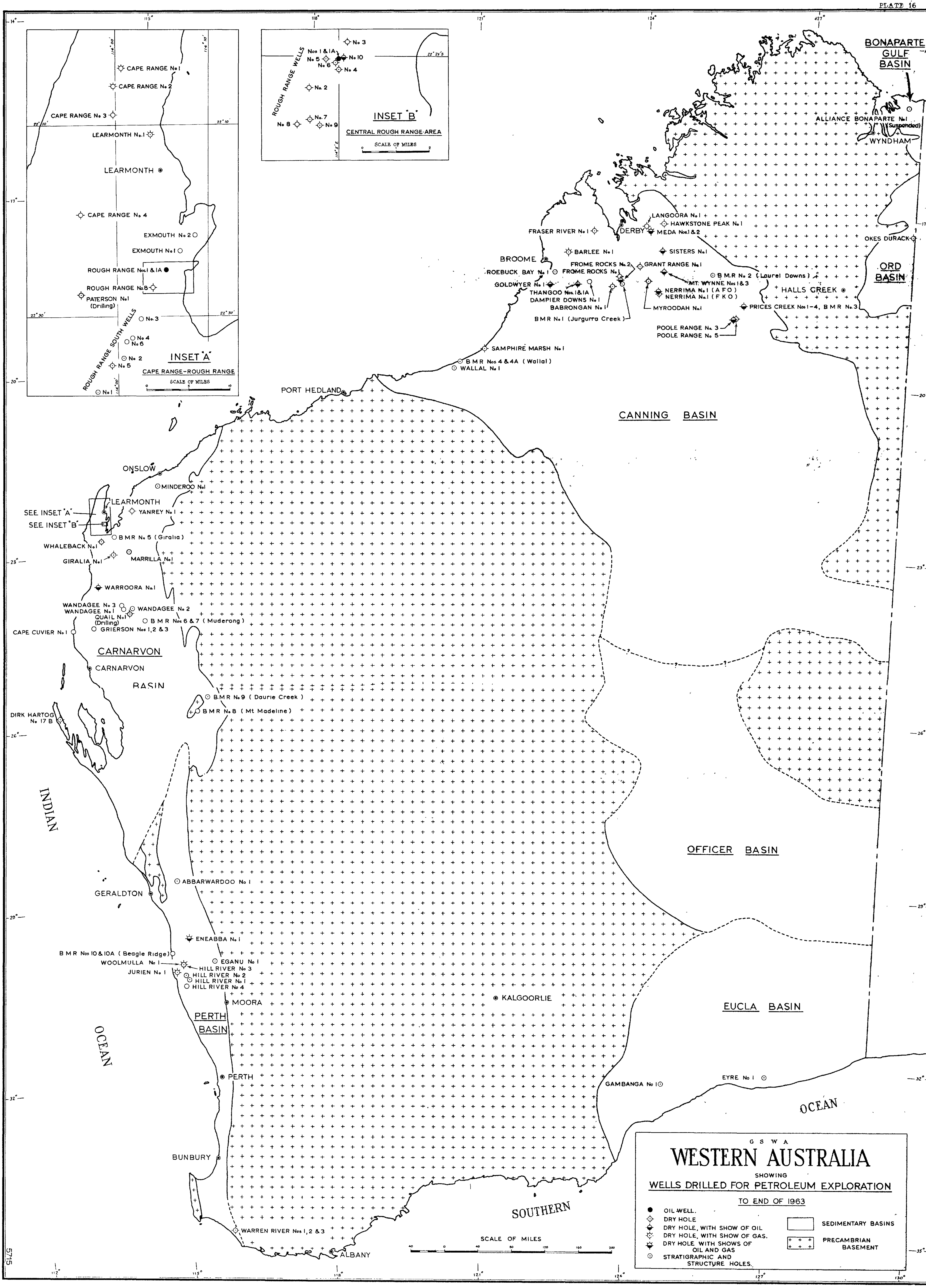
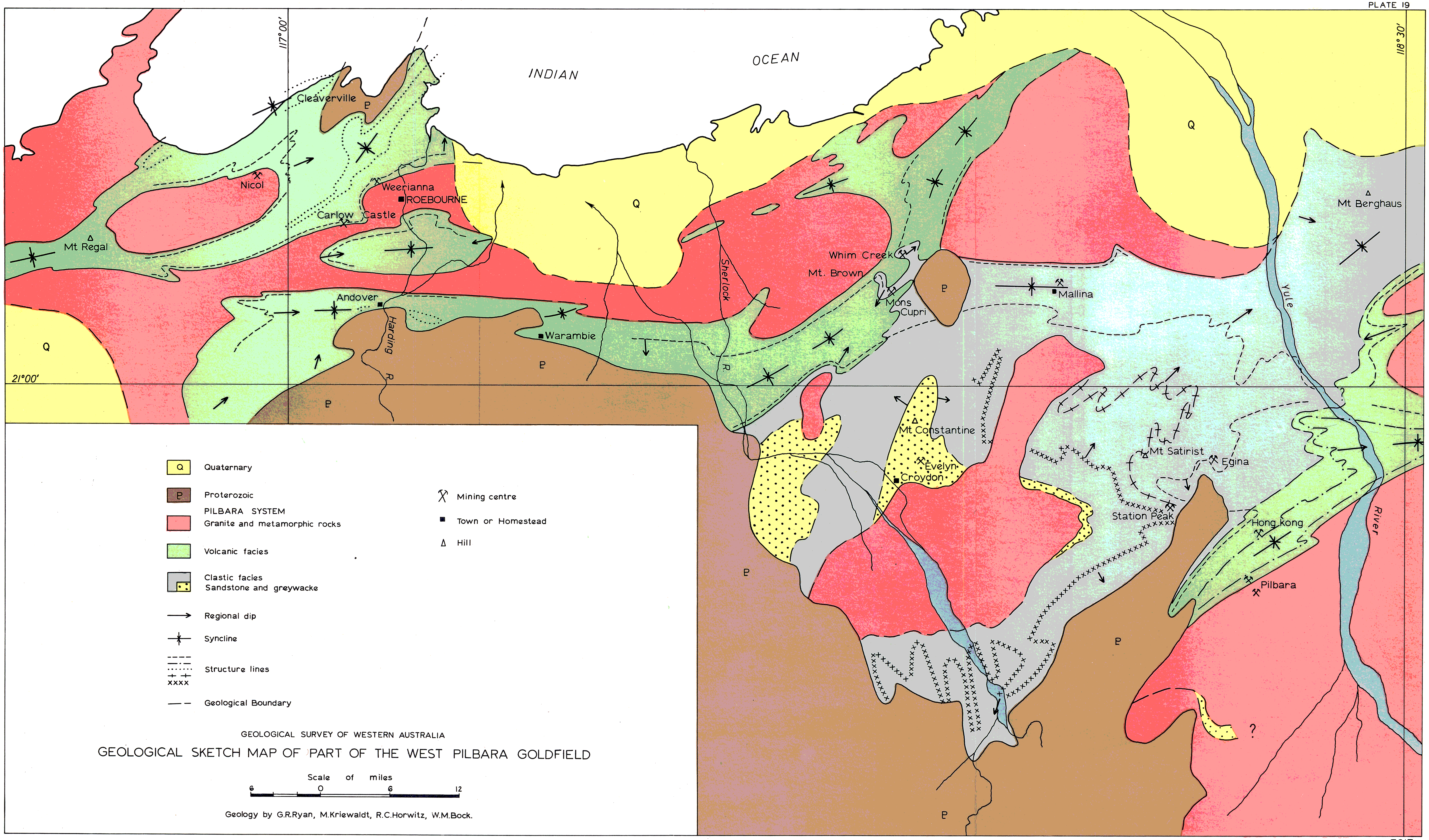

WESTERN AUSTRALIA
SHOWING
OIL HOLDINGS AT 31st Dec 1963
Licence to Prospect shown thus: ● 71H
Permit to Explore shown thus: 30H
SCALE OF MILES
150 100 50 0 150
INDIAN OCEAN
SOUTHERN OCEAN
WYNDHAM
DERBY
BROOME
HALLS CREEK
PORT HEDLAND
ROEBOURNE
Barrow Is
ONSLOW
CARNARVON
GERALDTON
KALGOORLIE
PERTH
ESPERANCE
ALBANY
224H
223H
221H & 222H
220H
213H
142H
127H
106H
165H
167H
166H
30H
217H
151H
216H
203H
152H
205H
153H
207H
206H
28H
161H
147H
158H
159H
134H
157H
148H
135H
193H
156H
136H
27H
178H
172H
173H
209H
174H
225H
171H
210H
175H
177H
214H
199H
211H
8129

PLATE 16



5715


INDIAN
OCEAN
117°00'
118°30'
21°00'
Cleaverville
Nicol
Weerianna
ROEBOURNE
Carlow Castle
Mt Regal
Andover
Harding R.
Warambie
Sherlock R.
Whim Creek
Mt. Brown
Mons Cupri
Mallina
Mt Berghaus
Yule River
Mt Constantine
Evelyn
Croydon
Mt Satirist
Egina
Station Peak
Hong kong
Pilbara
Q
P
?
Quaternary
Proterozoic
PILBARA SYSTEM
Granite and metamorphic rocks
Volcanic facies
Clastic facies
Sandstone and greywacke
Regional dip
Syncline
Structure lines
Geological Boundary
Mining centre
Town or Homestead
Hill
GEOLOGICAL SURVEY OF WESTERN AUSTRALIA
GEOLOGICAL SKETCH MAP OF PART OF THE WEST PILBARA GOLDFIELD
Scale of miles
6 0 6 12
Geology by G.R.Ryan, M.Kriewaldt, R.C.Horwitz, W.M.Bock.

7917

Licenses to Prospect

No.	Name of Holder	Area in Square Miles	Date of Expiry of Current Tenure
56H	West Australian Petroleum Pty. Ltd.	200·0	22/2/64
57H	Westralian Oil Ltd.	196·0	29/9/63
58H	Associated Freney Oil Fields N.L.	120·0	27/10/64
59H	do. do. do.	113·4	27/10/64
60H	do. do. do.	113·2	27/10/64
61H	do. do. do.	112·5	27/10/64
62H	do. do. do.	112·5	27/10/64
63H	West Australian Petroleum Pty. Ltd.	117·7	17/2/64
66H	do. do. do.	200·0	18/1/64
67H	do. do. do.	199·4	20/4/64
68H	do. do. do.	195·1	17/5/64
69H	do. do. do.	175·1	17/5/64
70H	do. do. do.	192·8	17/5/64
71H	do. do. do.	187·1	17/5/64
72H	do. do. do.	194·7	17/5/64
73H	do. do. do.	188·7	17/5/64
74H	do. do. do.	186·0	17/5/64
75H	do. do. do.	190·8	17/5/64
76H	do. do. do.	192·9	17/5/64
77H	do. do. do.	196·2	17/5/64
78H	do. do. do.	189·7	17/5/64
79H	do. do. do.	198·8	17/5/64
80H	do. do. do.	188·9	17/5/64
81H	do. do. do.	193·4	17/5/64
82H	do. do. do.	198·1	17/5/64
83H	do. do. do.	193·1	17/5/64
84H	do. do. do.	187·4	17/5/64
85H	do. do. do.	187·0	17/5/64
86H	do. do. do.	189·0	17/5/64
87H	do. do. do.	189·0	5/1/64
88H	Hawkstone Oil Co. Ltd.	189·0	29/2/64
89H	West Australian Petroleum Pty. Ltd.	192·0	27/2/64
90H	do. do. do.	160·5	27/2/64
91H	do. do. do.	133·8	27/2/64
92H	do. do. do.	180·1	27/2/64
93H	do. do. do.	195·4	27/2/64
94H	do. do. do.	186·5	27/2/64
95H	do. do. do.	199·9	12/6/64
96H	do. do. do.	100·0	18/3/64
97H	do. do. do.	191·4	26/7/64
98H	do. do. do.	200·0	26/7/64
99H	do. do. do.	190·5	4/12/64
100H	do. do. do.	200·0	4/12/64
101H	do. do. do.	193·6	17/12/64
102H	do. do. do.	195·6	13/1/65
103H	do. do. do.	200·0	20/5/65
104H	do. do. do.	197·9	6/6/65
105H	do. do. do.	196·0	14/8/65
106H	do. do. do.	200·0	12/9/65
107H	do. do. do.	200·0	Applied for

DRILLING

The positions of all wells drilled for petroleum exploration in Western Australia to the end of 1963 are shown on Plate 16.

Permit to Explore 27H

Permit to Explore 27H is held by West Australian Petroleum Pty. Ltd. and covers the Perth Basin. The company completed one oil-test well (Woolmulla No. 1) and one stratigraphic hole (Eganu No. 1) in the permit area during 1963. Both had been commenced during the previous year. Details of these wells are as follows:—

Eganu No. 1

Type: Stratigraphic.

Latitude and Longitude: 29° 59′ 05″ S., 115° 49′ 35″ E.

Elevation: Ground 772 feet, kelly bushing 777 feet.

Date commenced: 30th December, 1962.

Date completed: 16th January, 1963.

Total depth: 1,970 feet.

Bottomed in: Upper Jurassic.

Woolmulla No. 1

Type: Oil-test.

Latitude and Longitude: 30° 01′ 24″ S., 115° 11′ 28″ E.

Elevation: Ground 382 feet, derrick floor 394 feet.

Date commenced: 3rd November, 1962.

Date completed: 3rd March, 1963.

Total depth: 9,224 feet.

Bottomed in: Precambrian granite.

Remarks: Gas showings recorded in the Lower Triassic and Lower Permian sediments, with traces of fluorescence in the Lower Triassic.

Permit to Explore 28H

Permit to Explore 28H is held by West Australian Petroleum Pty. Ltd., and covers the Carnarvon Basin. Two stratigraphic holes and one oil-test well were completed in the Permit area during 1963. Two oil-test wells were still being drilled at the end of the year. Details are as follows:—

Marrilla No. 1

Type: Stratigraphic.

Latitude and Longitude: 22° 55′ 45″ S., 114° 30′ 00″ E.

Elevation: Ground 155 feet, kelly bushing 160 feet.

Date commenced: 7th March, 1963.

Date completed: 2nd April, 1963.

Total depth: 1,498 feet.

Bottomed in: ? Silurian.

Minderoo No. 1

Type: Stratigraphic.

Latitude and Longitude: 21° 50′ 40″ S., 115° 04′ 40″ E.

Elevation: Ground 35 feet, kelly bushing 40 feet.

Date commenced: 9th April, 1963.

Date completed: 27th April, 1963.

Total depth: 2,000 feet.

Bottomed in: Upper Carboniferous.

Paterson No. 1

Type: Oil-test.

Latitude and Longitude: 22° 27′ 34″ S., 113° 55′ 56″ E.

Elevation: Ground 320 feet, derrick floor 331 feet.

Date commenced: 18th July, 1963; drilling ahead at 5,662 feet on 31st December, 1963.

Quail No. 1

Type: Oil-test.

Latitude and Longitude: 23° 57′ 04″ S., 114° 29′ 57″ E.

Elevation: Ground 376 feet, derrick floor 388 feet.

Date commenced: 19th May, 1963; drilling ahead at 11,125 feet on 31st December, 1963.

Whaleback No. 1

Type: Oil-test.

Latitude and Longitude: 22° 43′ 35″ S., 113° 51′ 37″ E.

Elevation: Ground 176 feet, derrick floor 187 feet.

Date commenced: 30th July, 1963.

Date completed: 23rd October, 1963.

Total depth: 5,013 feet.

Bottomed in: Lower Permian.

Remarks: Slight oil staining observed in the basal Cretaceous unit; brackish and salty water recovered on testing.

Permit to Explore 127H

Permit to Explore 127H is held by Alliance Oil Development Australia N.L. and covers the Western Australian part of the Bonaparte Gulf Basin. The company commenced its first exploratory well in the basin during 1963, in association with Alliance Petroleum Australia N.L., and drilling was suspended in December for the duration of the wet season. Details of the well are as follows:—

Alliance Bonaparte No. 1

Type: Stratigraphic.

Latitude and Longitude: 15° 00′ 50″ S., 128° 44′ 35″ E.

Elevation: Ground 396 feet.

Date commenced: 18th July, 1963.

Date suspended: 15th December, 1963, at 10,291 feet.

GEOPHYSICAL OPERATIONS

Seismic

During the year seismic operations were conducted in the Perth, Carnarvon, Canning, Bonaparte Gulf, and Officer Basins.

West Australian Petroleum Pty. Ltd. carried out operations totalling some 14 party-months in Permit 27H (Perth Basin), 11½ party-months in Permit 28H (Carnarvon Basin), 12 party-months in Permit 30H (Canning Basin) and a half party-month in Permit 217H (Carnarvon Basin).

Alliance Oil Development Australia N.L. conducted four party-months of seismic work in Permit 27H (Bonaparte Gulf Basin).

In the Officer Basin, Hunt Oil Co. conducted a reconnaissance seismic survey on Permits 147H and 159H, occupying about two party-months.

Hackathorn Oils Pty. Ltd. carried out reconnaissance seismic surveys amounting to two party-months in the eastern part of the Canning Basin on Permit 151H.

The Bureau of Mineral Resources continued a programme of regional seismic lines across the Perth and Carnarvon Basins (Permits 27H and 28H), occupying about six party-months.

Gravity

Gravity surveys were carried out during the year in the Perth, Canning, and Officer Basins.

West Australian Petroleum Pty. Ltd. carried out surveys amounting to 8½ party-months in the Perth Basin (Permit 27H) and six party-months in the Canning Basin (Permit 30H). In the Officer Basin, Hunt Oil Co. conducted gravity surveys amounting to some 29 party-months in Permits 147H, 148H, 159H, and 134H. Hackathorn Oils Pty. Ltd. conducted a half party-month of gravity work on Permit 151H (Canning Basin). Hawkstone Oil Co. established 82 gravity stations on islands of the Houtman Abrolhos (Permit 193H).

Aeromagnetic

Reconnaissance aeromagnetic surveys were conducted during the year by Hackathorn Oils Pty. Ltd. and Woodside (Lakes Entrance) Oil Co. N.L. Hackathorn's survey occupied some two weeks of flying and covered part of Permit 151H. Woodside flew a number of lines over its off-shore lease opposite the Canning Basin, and this involved about two days of flying.

GEOLOGICAL OPERATIONS

Geological field investigations played a relatively small part in the exploration programmes of companies searching for oil in Western Australia during 1963, though there was more activity than in the previous year.

In the Canning Basin West Australian Petroleum Pty. Ltd. employed from two to three geologists for four months on field studies in the eastern and south-central parts of the basin. In the extreme eastern part of the basin Hackathorn Oils Pty. Ltd. carried out reconnaissance field geological studies amounting to some 95 man-days.

Hunt Oil Co. carried out about one month's field geological work in the Officer Basin for three geologists. The company also conducted a comprehensive photogeological study of the permit areas which it administers in this basin.

The Bureau of Mineral Resources carried out a detailed geological survey of the Western Australian part of the Bonaparte Gulf Basin, and this employed four geologists for five months. The Geological Survey of Western Australia continued field studies in the southern and central parts of the Perth Basin amounting to three months for one geologist and two months for another. The Geological Survey also continued the Lennard Shelf project in the Canning Basin, and this employed two geologists for four months.

Other geological work connected with the search for oil in this State during 1963 was mainly concerned with the review of information obtained previously and the application of this information to the results of exploratory wells and geophysical investigations. Some companies carried out other brief field surveys apart from those mentioned above.

NOTES ON THE PRECAMBRIAN BETWEEN KALGOORLIE AND NORSEMAN

By R. C. Horwitz and J. Sofoulis

ABSTRACT

Recent studies in the Archaean of the Kalgoorlie-Norseman area show that the layered rocks can be subdivided into two main units, both containing basic igneous rocks and sediments. The lower unit is distinguished by the presence of acid volcanic flows and sills.

In some areas, clastic sediments become coarser and pass into conglomerates. This passage is accompanied by thinning of the beds.

These features and their distribution suggest a basin of subsidence flanked by areas of shallow-water deposition.

Repeated ingneous activity and vulcanism has occurred along the flanks of this basin. The acid igneous activity and the different environments of deposition have played an important part in the primary distribution of various metals.

A chronology of all basic and acid igneous activity as well as sedimentation, has been established for the Precambrian of this area.

INTRODUCTION

The subdivision of Archaean rocks into those of basic igneous or of sedimentary origin has generally formed the basis for the nomenclature appearing in past literature. Broadly, these subdivisions were distinguished as greenstones (predominantly basic igneous rocks) and whitestones (predominantly sediments), and it was generally accepted that the greenstones were stratigraphically lower in the sequence than the sediments.

Recent mapping in the area between Kalgoorlie and Norseman shows that basic igneous rocks interfinger with and pass laterally into sediments, and that basic volcanic rocks occur at different stratigraphic levels. Plate 17 is a geological sketch map of the area. A chronology of all major Precambrian units follows.

ARCHAEAN

The layered sequence can be subdivided into two main units both containing basic igneous rocks and sediments. The lower unit is distinguished by the presence of acid volcanic flows and sills.

Lower Unit

This unit contains basic igneous rocks with associated chemical sediments (cherts and calcareous rocks). These are intercalated with acid volcanic rocks and beds of tuffaceous greywacke. The acid flows are porphyritic, often agglomeratic or brecciated, and associated with fine and coarse clastics as well as boulder beds.

These boulder beds contain elements of granite and porphyry as well as representatives of basic igneous rocks, clastic and chemical sediments.

Two environments of deposition have been deduced within this lower unit. The separate lithologies of these environments locally have sharply defined limits while in others they appear to be gradational or show interfingering.

One environment is characterised by a thick monotonous sequence of tuffaceous greywacke with abundant preconsolidation slump features, and a group of iron formations as the only major variant. This environment of deposition occupies the area east of Lake Lefroy and Lake Cowan and south of Randell Siding. The other environment of deposition flanks this area. Here the acid and basic volcanics appear in the sequence, the clastics get coarse, the beds thinner, and local disconformities are present.

This evidence suggests a basin of subsidence flanked by areas of shallow water deposition with associated volcanicity.

KALGOORLIE

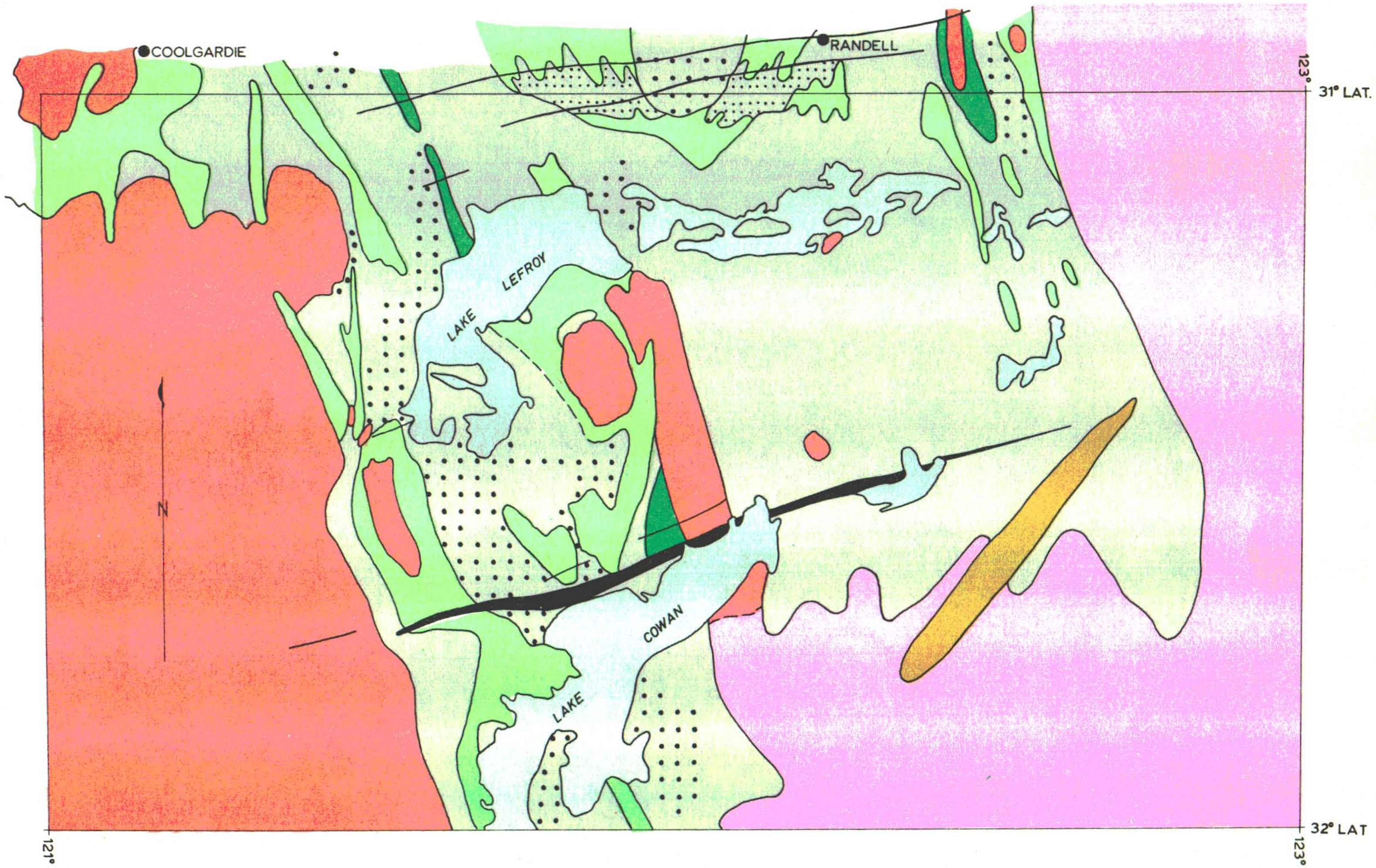
REFERENCE

PROTEROZOIC

- Sediments
- Granites and charnockitic gneisses
- Basic dyke suite

ARCHAEAN

- Granite
- Basic volcanic flows and sediments
- Tuffaceous greywake and acid sills
- Acid volcanic flows agglomerate & conglomerates
- Basic volcanic flows



GEOLOGICAL SURVEY OF WESTERN AUSTRALIA

GEOLOGICAL SKETCH MAP OF THE PRECAMBRIAN BETWEEN KALGOORLIE AND NORSEMAN

SCALE 1:1,000,000

20 10 0 20 40

NORSEMAN

7915

PLATE 17

7915

Upper Unit

The upper unit overlies the lower unit and similarly contains basic igneous rocks and associated sediments. Lateral equivalents of these rocks are also represented by a greywacke facies, but acid flows and sills are absent.

Within this unit, the distribution of basic igneous rocks is restricted to the flanks of the same basin of subsidence recognised in the lower unit.

Other Units

Both units are intruded by a suite of acid dykes and plugs. These are locally emplaced along schistosity planes and are in places tightly folded. Petrographically these intrusive rocks cannot be distinguished from some of the acid flows and sills of the lower unit. (Trendall, pers. comm.)

Still younger gabbroic sills (commonly referred to as "younger greenstones") occur along the margins of the basin of subsidence within the areas of volcanicity. They are mainly concordant.

Granite is younger than these gabbro sills, with some porphyritic forms being lithologically similar to the older acid igneous rocks.

FOLDING AND SCHISTOSITY

Two directions of folding have been noted. In the region between Kalgoorlie and Norseman, this has resulted in fold structures that have yielded domes and basins. There are two main arrangements of fold axes; one is oriented a little to the west of north and the other in a northeast direction. These trends are also those of the regions of volcanicity that flank the basin of subsidence. The concept of interference type folding as developed by O'Driscoll (1962) can be applied and in this area has produced broad anticlines and tight synclines that are in general overturned to the northeast.

A strong schistosity within the rocks is related to this folding and appears to have been produced before some of the acid dykes and plugs were emplaced. The northerly trending zones forming the marginal contacts of the basin of subsidence often show planes of schistosity that are strongly contorted. In these areas, attitudes of minor dragfolds are often anomalous with flat and steep plunges and with right and wrong way drags imposed on bedding planes and on contacts of all igneous bodies. This suggests that, along these zones, there has been superimposed folding that may have been effective even in post Archaean times.

ARCHAEAN GRANITE EMPLACEMENTS

A vast area of granite flanks and embays the metamorphic rocks in the western part of the area. Other cupola granites are emplaced within the metamorphic rocks and mainly confined to anticlinal parts of the lower unit. At regional scale these granites tend to be concordant, but in detail they are intrusive. They intrude higher stratigraphic levels within the margins of the basin of subsidence in the zones of shallow water environment and are emplaced at the highest stratigraphic levels in the areas interpreted as the hinge lines of the basin of sedimentation.

Complex lithia pegmatites are preferentially confined to the basic igneous rocks that flank the granites.

PRIMARY MINERALISATION

The relationship of igneous activity, metamorphism and ore-formation has been commented on by Prider (1945). The identity of the factors controlling the regional distribution of igneous and sedimentary rocks; the tuffaceous nature of many of the sediments; and the similarity between acid and basic igneous rocks of all ages; all suggest a close link between subsidence, sedimentation, and igneous activity in the Archaean of this region.

Primary mineralisation appears to be related to the acid igneous activity with gold mineralisation largely restricted to the areas with volcanicity and fringing the acid igneous rocks of all ages. In addition some acid igneous rocks locally contain sulphide mineralisation and carry small amounts of gold.

The acid volcanics and intimately associated greywackes locally contain copper mineralisation within the marginal areas, and an iron formation has been traced from the acid flows to the area without volcanic rocks.

Thus the acid igneous activity and the different environments of deposition have played an important part in the primary distribution of various metals.

PROTEROZOIC ROCKS

All of the Archaean members are cut by a suite of basic dykes aligned in an east-northeast direction. The suite is distinguished as forming a major tectonic lineament in the southern portion of this Archaean block and is referred to the Lower Proterozoic. (Sofoulis and Bock, 1962.)

The dykes are truncated by a younger granite which appears to have followed, in its emplacement, the eastern edge of the Archaean basin of sedimentation. Further east this younger granite passes into granulitic and charnockitic rocks that have been assigned to the Lower Proterozoic (Sofoulis, 1962).

Flat-lying sediments, quartzites, shales and phyllitic slates unconformably overlie the Archaean and Lower Proterozoic in the southeast part of the area. These have been described as the Woodline Beds and are assigned to the Upper Proterozoic (Sofoulis and Bock, 1962).

A regional distribution of these younger Precambrian groups is shown on the accompanying sketch map (Plate 17).

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A REAPPRAISAL OF THE ARCHAEAN OF THE PILBARA BLOCK

By G. R. Ryan

ABSTRACT

Recent mapping in the West Pilbara Goldfield suggests that there is no major time break between the Warrawoona succession and the Mosquito Creek succession. On the 1:250,000 sheet areas of Roebourne and Pyramid two successions which are lithologically similar to these form lateral equivalents of one another and represent two distinct facies within a single geosynclinal cycle which ended in intrusion and orogeny. The name Pilbara System is extended to include all the rocks belonging to this cycle.

The depositional units, which include a volcanic facies and a clastic facies, have been included in a newly-created unit, the Roebourne Group. The angular break between the Mosquito Creek succession and the Warrawoona succession is considered to be of local significance only, and both successions are equated with the Roebourne Group.

The correlation of the "Mosquito Creek System or Series" with the Lower Proterozoic of northern Australia, and the Archaean of central Australia and South Australia is no longer considered valid.

INTRODUCTION

The Pilbara Block consists of a series of low grade metamorphic rocks intruded by granite, and forms an elongate belt stretching some 300 miles from Cape Preston on the northwest coast of Western Australia east-southeast to the vicinity of Eastern Creek mining centre (see Plate 18). The block is flanked to the south by a sedimentary basin of Proterozoic age, and to the north by the Canning Basin which contains sediments of Phanerozoic age underlain at least in part by Proterozoic rocks (Traves, Casey and Wells, 1956). The area is of interest because of the metalliferous deposits of the metamorphic rocks. A pegmatite from Wodgina, south of Port Hedland, gave an age "in excess of 2,700 m.y." (Wilson and others, 1960) thus placing the series in the Archaean.

PREVIOUS INVESTIGATIONS

In 1903, A. Gibb Maitland began the first comprehensive survey of the Pilbara Goldfield within which lies the greater part of the known mineralisation of the block. In the course of this work he distinguished two stratigraphic series. The older, consisting of a sedimentary group and an igneous group, he named the "Warrawoona Beds or Series" after the type area at Warrawoona, south of Marble Bar. The younger, consisting of grits, quartzites and shales, he named the "Mosquito Creek Beds or Series" after the type area at Mosquito Creek east of Nullagine Township. The division was made on the basis of a conglomerate bed containing elements of Warrawoona type at the base of the Mosquito Creek beds on North Dromedary Hill and South Dromedary Hill (Maitland 1904: and 1905). Subsequently the presence of an angular unconformity at the base of the Mosquito Creek beds at Eastern Creek was inferred by Finucane (1939).

Gently dipping sedimentary and volcanic rocks overlie both the above series in many parts of the area, and were named by Maitland (1904) the Nullagine Beds. Subsequently the Ashburton Beds, named by Maitland (1909), were correlated with the "Mosquito Creek Series" on lithological grounds, as were similar beds in the Peak Hill Goldfield to the south of the Pilbara Block.

From these beginnings there evolved a threefold sub-division of the Precambrian in Western Australia. It would not be possible to list all the many contributions to this evolution, but a few pertinent publications will be mentioned, wherein may be found a more complete bibliography.

Maitland (1924) subsequently suggested that "a very intimate and close relationship (might exist) between the Warrawoona and Mosquito Creek Beds" and Blatchford (1930) also questioned the validity of the "Mosquito Creek Series." Blatchford equated the "Warrawoona Series" with the Kalgoorlie Series on similar lithology, but because the Yilgarn Series was then believed to be older than the Kalgoorlie Series he suggested that the "Mosquito Series," with a lithology similar to that of the Yilgarn Series, should be more closely examined. Later the Yilgarn Series was placed above the Kalgoorlie Series, thus permitting a direct correlation between the two areas (Forman, 1937). Woodward (1911) mapped the primarily sedimentary succession around Whim Creek and Station Peak as "Metamorphic Sediments" and "Banded Cherts and Quartzites." He made no distinction in age between these and his "Basic Igneous" rocks of the Roebourne area.

In 1932 David assigned the "Warrawoona Series" to the "Archaeozoic," the "Mosquito Series" to the "?older Proterozoic" and the Nullagine Series to the "younger Proterozoic." Browne, editor of David (1950), placed the same divisions in the Lower, Middle, and Upper Precambrian. Both these workers recognised a post-Warrawoona Pilbaran Orogeny, and a post-Mosquito Creek Houghtonian Orogeny. They correlated the "Nullagine Series" with the Adelaide System of South Australia, and the "Mosquito Series" with the metallogenetic provinces of Broken Hill, Mt. Isa, and the Northern Territory. Hills (1946) made the same correlation from a tectonic viewpoint. Systemic names were used for the three divisions by Fairbridge (1953).

In more recent years a difference of opinion between Australian geologists is reflected by Clarke, Prider and Teichert (1944) who placed the "Mosquito Creek Series" in the Archaean with the "Warrawoona Series"; and Noakes (1953) who retained the "Mosquito Creek Series" in the Lower Proterozoic. A Lower Proterozoic age for Warrawoona-type rocks flanking the Canning Basin was suggested by Traves and others (1956). However, in general, agreement was maintained on the correlation of the "Mosquito Creek Series" with the Lower Proterozoic elsewhere in Australia.

A radical departure from the accepted correlation was that of Sofoulis (1962) who suggested that the rocks of the Warburton Range area near the border between South Australia and Western Australia might be Lower Proterozoic and equivalent in age to the Nullagine elsewhere in Western Australia, the "Archaean" of Central and South Australia, and the Lower Proterozoic rocks mapped by Commonwealth Geologists in the Northern Territory. A more detailed correlation between the Warburton Range area and South Australian geology was made by Horwitz and Sofoulis in 1963. Evidence in the West Pilbara Goldfield suggests that there may not be a great break in time between the base of the Nullagine (the Fortescue Group of MacLeod and others, 1963) and the underlying Pilbara System (Kriewaldt, 1964).

Since 1956 most of the Pilbara Block and the Proterozoic rocks to the south have been mapped by the Geological Survey of Western Australia at a scale of 1:250,000. As a result of this work a substantial reappraisal of correlations within the Precambrian of this area has become necessary. Much of this work is still in preparation, and little is published. Where possible sources have been quoted but many of the ideas contained herein have arisen out of discussion within the Geological Survey so that a particular source is not always evident. In particular the very great contribution, both in the field and in the office, of M. Kriewaldt is acknowledged.

THE PILBARA SYSTEM

The name Pilbara System was introduced by Noldart and Wyatt (1962, p. 96) for the folded and metamorphosed successions of the Archaean in the Pilbara Goldfield. However, they followed earlier workers in separating the Mosquito Creek "succession" from the Warrawoona "succession." They also established within the Mosquito Creek the Gorge Creek Formation, consisting of "contorted massive jaspilites with associated quartzites and fine conglomerates etc." (p. 68); and they made a distinction between the predominantly hematitic jaspilite of this formation and the magnetitic-limonitic iron of the Warrawoona jaspilites (p. 106). Low (1963) correlated the Gorge Creek Formation with similar rocks at Mt. Goldsworthy, the Ord Ranges, and elsewhere on the Port Hedland 1:250,000 sheet area. He also suggested that clastic sediments around Cookes Hill, near the western edge of the area might be the equivalent of the Gorge Creek Formation.

No unconformity has been seen at the base of the Gorge Creek Formation, but there has been granite intrusion and granitisation both of this formation and of the Mosquito Creek beds in the type area.

Traves and others (1956) described a hematitic jaspilite formation unconformably overlying Warrawoona-type beds north of Yarrie Homestead, east of the Port Hedland sheet area. Although they correlate this with the jaspilite at Marble Bar, a better correlation, based on the more recent work of Noldart and Wyatt, is with the jaspilite of the Gorge Creek Formation.

West of Roebourne a similar jaspilite named the Cleaverville Formation by Ryan and Kriewaldt (1964), overlies the Warrawoona-type Regal Formation with apparent conformity. They consider that the Cleaverville Formation and the Regal Formation together are the lateral equivalent of a succession of clastic sediments which crop out around Mt. Berghaus. The beds at Mt. Berghaus are the same as those around Cookes Hill which Low believes to be the equivalent of the Gorge Creek Formation.

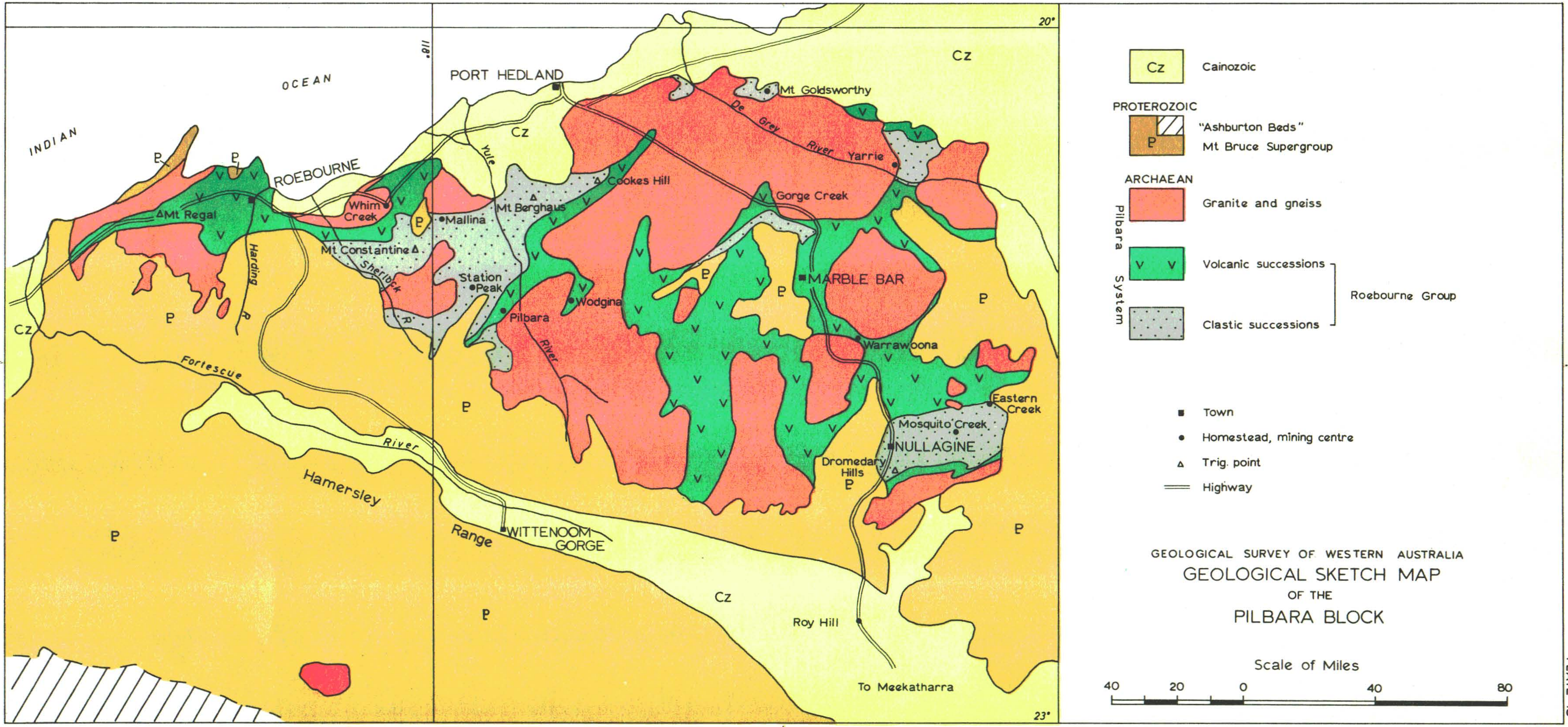

PLATE 18

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Two distinct facies within the Pilbara System are recognised by Ryan and Kriewaldt. A volcanic facies, which is typically developed west of Roebourne, consists primarily of volcanic rocks and chemical sediments with clastic rocks at the base overlying gneiss and metasomatised members of the succession. The lower and middle members of this succession are lithologically similar to the Warrawoona beds described by Maitland. The uppermost Cleaverville Formation has already been mentioned. Facies changes within the succession, including a local disconformity with overlying conglomerate below the Regal Formation, have been described by Horwitz (1963).

A much thicker clastic facies is typically developed in the vicinity of Mt. Satirist. It consists principally of pelites with coarser clastic assemblages towards the top and bottom; and within it are thin discontinuous formations which are lithologically similar to rocks in the volcanic facies.

The upper part of this succession near Mallina homestead is comparable in lithology with the Mosquito Creek beds of the type area; and further west is represented by the greywackes which are equated with the Gorge Creek Formation. Because of a lack of continuity in outcrop the precise correlation between the two facies is not clear.

The clastic facies may be wholly equivalent to the volcanic facies, or possibly only the upper part may be equivalent. Furthermore, if the latter be the case and the lower part of the clastic succession older, then it may be absent below the volcanic suite; or it may be incorporated in the gneiss which everywhere appears to form the base of this suite.

As a result of the mapping in the West Pilbara Goldfield considerable doubts were raised as to the existence of a separate "Mosquito Creek Series." The placing of the Ashburton Beds in the Proterozoic by Daniels and Halligan (1964) emphasised these doubts. In September, 1963, a brief trip was made to the type area of "Mosquito Creek Series" by the author in company with M. Kriewaldt, A. F. Trendall and W. N. MacLeod of the Geological Survey of Western Australia. Several conclusions were drawn:—

(a) There is marked difference in dip and strike between the Eastern Creek Formation (Noldart and Wyatt, 1962) and the underlying Warrawoona succession at Eastern Creek. Although the contact is obscured the presence of an angular break seems probable.

(b) A traverse east of North and South Dromedary Hills across the southern boundary of the Mosquito Creek succession revealed no sign of the Dromedary Conglomerate (Noldart and Wyatt, 1962) or of a break between the Mosquito Creek succession and the underlying Warrawoona succession.

(c) The Budjan Creek Formation (Noldart and Wyatt 1962) may belong to the overlying "Nullagine" beds. A thick coarse basal conglomerate resembles a similar conglomerate immediately west of Nullagine Township which there forms the base of the "Nullagine" beds.

(d) Immediately below the Budjan Creek Formation, with a strike contiguous with that of the Mosquito Creek succession further to the east, lie laminated siliceous shale and shaly dolomite beds. These are thought to represent a transition from the pelitic Mosquito Creek succession to the siliceous and calcareous metasediments of the Warrawoona succession. The Budjan Creek Formation strikes almost at right angles to this, and is parallel to the overlying "Nullagine" Beds.

NOMENCLATURE

The Pilbara System as described by Noldart and Wyatt (1962) consists of the Warrawoona succession and the Mosquito Creek succession but specifically excludes the granite which they consider was intruded before the deposition of the younger succession. The use of *system* in this sense is considered to be invalid and it is therefore proposed to extend the Pilbara System to include all those rocks, sedimentary, extrusive, and intrusive, which lie below the base of the Fortescue Group as described by MacLeod and others (1963) and Kriewaldt (1964) in the Pilbara Block.

These rocks represent a complete geosynclinal cycle which began with the deposition of sedimentary rocks, encompassed acid and basic vulcanicity and intrusion, and culminated in orogenesis and granite invasion. The age of the system, based on the pegmatite at Wodgina (Wilson and others, 1960) must be greater than 2,700 million years and therefore Archaean. However it should not be confused with the Archaean of South Australia and the Northern Territory.

The use of time-rock terms within the Precambrian is the subject of much controversy which will continue until international agreement is reached on the limits of the various systems and the names to be applied to them. In the meantime such names as Mississippian, Agicondian, Adelaide System, Lewisian and many others continue to be used and their widespread acceptance and use is implicit recognition of their utility. Regardless of where the base of the Proterozoic may be set; of what subdivisions may be made within the Archaean; and of whether a major time break is present below the Mosquito Creek succession, the name Pilbara System denotes a specific group of rocks in a specific area which have been formed by a series of geological events, one of the latest of which has been dated: and it is considered that the use of the systemic name is of greater value than the still loosely defined Archaean.

Within the Pilbara System there are sedimentary rocks, volcanic rocks, and intrusive rocks. The first two together comprise a well defined and readily mapped rock-stratigraphic unit but this has not been studied in sufficient detail to define and name formally all the constituent members. In the West Pilbara Goldfield a volcanic facies and a clastic facies are apparently synchronous, whereas near Nullagine one overlies the other. Erosional breaks are present in various places at various stratigraphic levels, and although the one at Eastern Creek is the most pronounced it is still doubtful whether it represents a break in time of major importance. It is worth noting that no granitic elements have been found in the conglomerates at the base of the Mosquito Creek succession, nor has this succession been seen to overlie granite unconformably.

The names Warrawoona and Mosquito Creek have come to have a particular lithological, stratigraphic, and geographic connotation in Western Australian geology, and despite the fact that similar lithological assemblages are present in the West Pilbara Goldfield it is not considered advisable to extend either of these names to that area. It is therefore proposed to include the sedimentary and volcanic rocks of the Pilbara System within the West Pilbara Goldfield in the newly created Roebourne Group; and to equate this with both the Warrawoona succession and the Mosquito Creek succession.

The Pilbara System also includes acid and basic intrusives; and granitic rocks form broad domes with gneissic margins, around which the Roebourne Group and its equivalents are draped. Both Maitland (1904) and Noldart and Wyatt (1962) have suggested that an older basement might be represented in some of these domes, and Kriewaldt (1963) has compared them to the "mantled gneiss domes" of Eskola. However the contact between these domes and the Roebourne Group, the Warrawoona succession and the Mosquito Creek succession is marked by intrusion and metasomatism and no evidence of an unconformity has been adduced.

If, at some future date, the presence of a basement is established, then it would be excluded from the Pilbara System.

CONCLUSION

The existence of a separate major time-rock unit, the "Mosquito Creek System or Series," rested on the identification of successions in three areas as belonging to it. The "Ashburton Beds" have now been shown to belong to the Proterozoic; the rocks of the Whim Creek-Station Peak area to be an integral part of the Roebourne Group; and the beds of the type area at Mosquito Creek to be in all probability an upper clastic equivalent of the Roebourne Group separated from the underlying succession by a structural break of unknown significance. Granite intrusion prior to deposition of the Mosquito Creek succession has yet to be established.

In the West Pilbara Goldfield two environments are characterised by synchronous successions which differ little in lithology from the classic successions of the Pilbara Goldfield: and furthermore a broad correlation can be made between the two areas.

The Pilbara System is thus thought to represent a single geosynclinal cycle which culminated in the Pilbaran Orogeny. The Pilbaran Orogeny of David (1932) preceded the Mosquito Creek succession but in the light of the considerations given above it is now placed at the close of this succession. The first-formed rocks of this system constitute a distinct rock-stratigraphic unit which, in the West Pilbara Goldfield, has been called the Roebourne Group. Subdivisions within the group depend on more detailed mapping throughout the Pilbara Block and it is suggested that the names *Warrawoona* and *Mosquito Creek* be withheld pending the establishment of such subdivisions; and that in the meantime such rock units as are distinguished be designated formations or beds.

On a continental scale it is apparent that the Lower Proterozoic of other areas can no longer be equated with the "Mosquito Creek System or Series." A more suitable correlation might be made between the "Nullagine Beds" and the "Ashburton Beds" of Maitland (parts of the Mt. Bruce Supergroup of Daniels and Halligan, 1964), the Lower Proterozoic of the Northern Territory and N.W. Queensland, and the Archaean of South Australia and Central Australia.

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FACIES CHANGES IN THE ARCHAEAN OF THE WEST PILBARA GOLDFIELD

By G. R. Ryan and M. Kriewaldt

ABSTRACT

In the West Pilbara Goldfield the Archaean consists of an assemblage of volcanic and sedimentary rocks disposed around large granitic domes which may represent in part an older basement. Igneous intrusion and metasomatism is common at the contact between the granitic domes and the overlying rocks.

Two environments with corresponding facies are recognised within this assemblage: a trough of sedimentation occupied primarily by clastic rocks, and a marginal area occupied by a thinner succession of volcanic rocks and chemical sediments. The marginal area was one of relative instability, and contemporaneous erosion contributed material to the trough, within which sedimentation was apparently uninterrupted.

INTRODUCTION

This brief description of the Archaean geology of the West Pilbara Goldfield is based on field work by the authors and R. C. Horwitz and W. M. Bock in 1962, and further work by the authors in 1963. Prior to this, the main source of information on this area was the early work of A. G. Maitland, H. W. B. Talbot and H. P. Woodward (Maitland, 1909; Woodward, 1911); and the surveys of mineral areas by the Aerial, Geological and Geophysical Survey of Northern Australia between 1935 and 1940.

Although one of the oldest mineral fields in Western Australia the area has never realised its early promise with the exception of the ore body at Whim Creek which has been the largest producer of copper in the State. However, modern ore-search techniques have not yet been applied, and the field's deposits of gold, copper, lead, zinc, silver, antimony, cobalt, titanium, vanadium, beryl, lithium and chrysotile offer considerable scope for exploration.

The geology of part of the field and the localities referred to, are shown on Plate 19 and a diagrammatic section is shown in Plate 20.

GEOLOGY

Two successions with distinctive facies are here described: a volcanic facies from the area around and west of Roebourne, and a clastic facies from the area between Whim Creek, the Yule River and Mt. Satirist. The two successions are lateral equivalents. Similar successions have been recognised in the Pilbara Goldfield (Maitland, 1908; Noldart and Wyatt, 1962).

VOLCANIC FACIES

Ignoring for the moment the smaller-scale changes within the succession, this facies may be described, from top to bottom, as follows:

(3) *Cleaverville Formation.* — These beds, named from the Cleaverville Townsite north-west of Roebourne, consist of banded hematite, jaspilite, chert and shale with interbedded red and green pelites and some concordant bodies of granular green rocks of dubious origin. Manganese staining is present in places. The thickness is estimated at 2,000 feet. These beds are tentatively correlated with the jaspilite of the Gorge Creek Formation (Low, 1963).

(2) *Regal Formation.*—The type area for these beds is Mt. Regal some 26 miles west of Roebourne, where they consist of tough, blue to dark-coloured basic rocks, with pillow lavas and intercalated quartz-amphibole schists. Near Roebourne, in addition to the members described above, there are pyroclastic rocks and pale-coloured, granular and aphanitic acid rocks; serpentinites and altered basic rocks with chrysotile seams; altered granular green lavas(?) with intercalated bedded siltstone and massive chert beds; and beds of shale, siltstone and greywacke, most of which are tuffaceous. Signs of turbidity current activity, and intraformational breccias in the sedimentary rocks, point to some preconsolidation movement. Clastic rocks are more common in the area west and south-west of Andover homestead. To the east, the Regal Formation is represented principally by green, grey and dark aphanitic rocks including a spheroidal variety; a rock with clusters of acicular pyroxene crystals replaced by bastite; and porphyritic rocks with quartz and feldspar phenocrysts set in a blue to black aphanitic matrix which is banded in places.

At Whim Creek this unit passes laterally to slate. It is up to 10,000 feet thick, but more commonly about 7,000 feet thick.

(1) *Metasediments.*—Below the Regal Formation are calcareous and siliceous sedimentary rocks with minor clastic rocks. This unit includes banded chert with prase, green (nickeliferous) dolomite, and fuchsite schist, and has been used as a stratigraphic marker. Associated rocks include dolomite, and schists containing quartz, amphibole, andalusite, talc and mica; pelitic rocks, tuffaceous rocks and some lavas; and sandstone and conglomerate developed locally over a disconformity (Horwitz, 1963). This unit is typically underlain by, and involved in, a zone of intrusion and metasomatism associated with adjacent granitic domes. It has an estimated average thickness of 1,500 feet.

Near the Sherlock River, and eastwards to Mt. Brown and Whim Creek the Regal Formation, and its laterally equivalent slate, are underlain by an orange-weathering, dark to pale-green, granular, siliceous rock. At the western end of this belt the rock has the appearance of a fine breccia, whereas at the eastern end it has a spheroidal texture. At Whim Creek it is interbedded with the overlying slate and at Mons Cupri there is a bed of pebbles at the contact. Feldspar crystals occur in places. The rock forms a distinct mappable unit; is equated with the silica-rich rocks below the Regal Formation further west; and is considered to be a siliceous, possibly tuffaceous, mudstone in which feldspar has developed as a result of preconsolidation shearing and diagenesis.

The boundary between the three assemblages is everywhere transitional, and there is some interfingering. Jaspilite occurs within the upper part of the Regal Formation and lavas are intercalated with metasediments of the lowest unit. The base of the Regal Formation has been set at the top of the uppermost banded chert formation, where this is present, but in the area of the greatest development of lavas there are some lavas below this chert formation.

A distinction may be made between the iron-poor, sulphide-bearing lower banded chert assemblage with associated vulcanicity, and the iron-rich, hematitic and manganiferous upper banded iron formation with little or no associated vulcanicity. This conforms with the description of Noldart and Wyatt (1962, p. 106) of a lower magnetite-limonite jaspilite and an upper hematite jaspilite.

CLASTIC FACIES

The succession in the Mt. Satirist 1-mile sheet area is from top to bottom as follows:—

(3) The rocks of the upper assemblage are quartz sandstone, greywacke and shale with banded chert, some jaspilite, and thin bodies of amphibolite. The thickness is estimated at 3,000 feet. Around Mt. Berghaus, east of the Yule River, graded greywackes of turbidity current origin predominate, but to the south sandstone, shale and chemical sediments are more common. The time correlation between these two areas is not clear. The greywacke at Mt. Berghaus may be slightly younger.

(2) The thick middle assemblage consists predominantly of shale and calcareous shale with thin siliceous and ferruginous beds. The next most common rocks are the green-coloured to dark-coloured spheroidal aphanitic rocks with interbedded chert which lie towards the top of the succession north of Pilbara. These are equated with the Regal Formation which they resemble. Immediately below them are granular siliceous rocks similar to those which underlie the Regal Formation west of Mt. Brown. Towards the bottom of this middle assemblage there are restricted occurrences of jaspilite in the shale. Two horizons of gabbroic amphibolite, concordant with the bedding of the adjacent shales, are present. The lower amphibolite is the country rock for gold-bearing quartz reefs at Station Peak. At a higher level there is an association of ultramafic

rocks with greywacke and chert. Concordant bodies of porphyritic rock are found in many parts of the succession. The greywackes contain abraded and strained feldspar of a type identical with that of the quartz-feldspar porphyry, and A. F. Trendall (personal communication) considers that the greywacke is composed of material derived from the erosion of porphyritic rock. The total thickness is estimated at 30,000 feet, of which half lies stratigraphically above the granular siliceous rock of the "Mt. Brown type."

(1) Interbedded shale, sandstone, and greywacke occupy the lowest part of the succession and total some 10,000 feet in thickness. A concordant gabbroic amphibolite body lies towards the bottom of this succession. The base passes to a zone of metasediments flanking granite and gneiss.

On the southern side of this area at Pilbara, much of the lower part of this succession is absent. Banded cherts of the upper part pass downwards to hornblende schists, and then to gneiss and granite.

CORRELATION OF FACIES

There is no great resemblance between the two successions, and uncertainty as to the structure makes precise correlation somewhat difficult. However, certain tentative correlations may be made.

The most obvious correlation is that of the granular siliceous rock of the "Mt. Brown type," which lies below the Regal Formation at the Sherlock River, and below similar beds near Pilbara. The upper clastic succession which crops out from Mallina to Mt. Berghaus also overlies these beds. In this area outcrops are rare, but there are a few of a rock type similar to the Regal Formation.

The greywackes at Mt. Berghaus are the same as those at Cookes Hill on the Port Hedland 1:250,000 sheet area, which Low (1963) has suggested might be the equivalent of the Gorge Creek Formation. Westwards from Mallina this clastic succession passes to the Regal Formation and probably also to the overlying Cleaverville Formation.

Below the "Mt. Brown type" rocks in the clastic facies are ultramafic rocks, cherts and calcareous sediments which could be equated with the metasediments below the Regal Formation at Roebourne.

There appears to be no equivalent in the volcanic facies of the lowermost clastic rocks of the clastic facies. These were either never deposited, are attenuated, or have been incorporated in the gneiss which everywhere underlies the volcanic rocks. However, the absence of coarse clastics is a characteristic of the volcanic facies, and so it seems unlikely that this lowermost clastic assemblage was ever laid down.

CONCLUSION

The presence of a sedimentary basin within which clastic deposition has taken place presupposes the existence of a basement to the Archaean rocks. However, no evidence for this has been adduced although several workers have suggested that such a basement may be represented by the massive granitic domes now exposed in the Pilbara area. Whether this is the case or not, the first event of the chronology of the Pilbara System appears to have been the deposition of a succession of coarse clastics in what may be presumed to have been a subsiding trough.

Subsequently, vulcanicity developed along the margin of the trough, with the concomitant formation of beds of siliceous and calcareous matter. Within the trough, where clastic sedimentation continued, these chemical formations were diluted by pelitic material to the extent that banded chert is represented by siliceous mudstone and dolomite by calcareous shale. A tuffaceous element is present, but lavas failed to reach the centre of the trough. Contemporaneous erosion on the higher marginal areas is suggested by the local disconformity, and by the presence in greywacke of feldspar derived from porphyry.

Volcanic activity died away in the closing stages, and early orogenic movement caused local erosion and the deposition of coarser clastic rocks. Because of the mountain building activity the loci of deposition may have shifted, giving rise to clastic successions overlying older volcanic assemblages. However, periods or areas of tranquillity permitted the formation of jaspilite, and it is possible that early rising anticlines created barred basins in which chemical sedimentation took place. An oxidising environment prevailed in contrast to the reducing environment characteristic of the volcanic phase.

The distinction between the two facies, in fact, appears to have been between an area of volcanic activity and minimal clastic sedimentation, and a trough where an abundance of clastic material diluted the products of the contemporaneous vulcanicity.

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THE FORTESCUE GROUP OF THE ROEBOURNE REGION, NORTH-WEST DIVISION

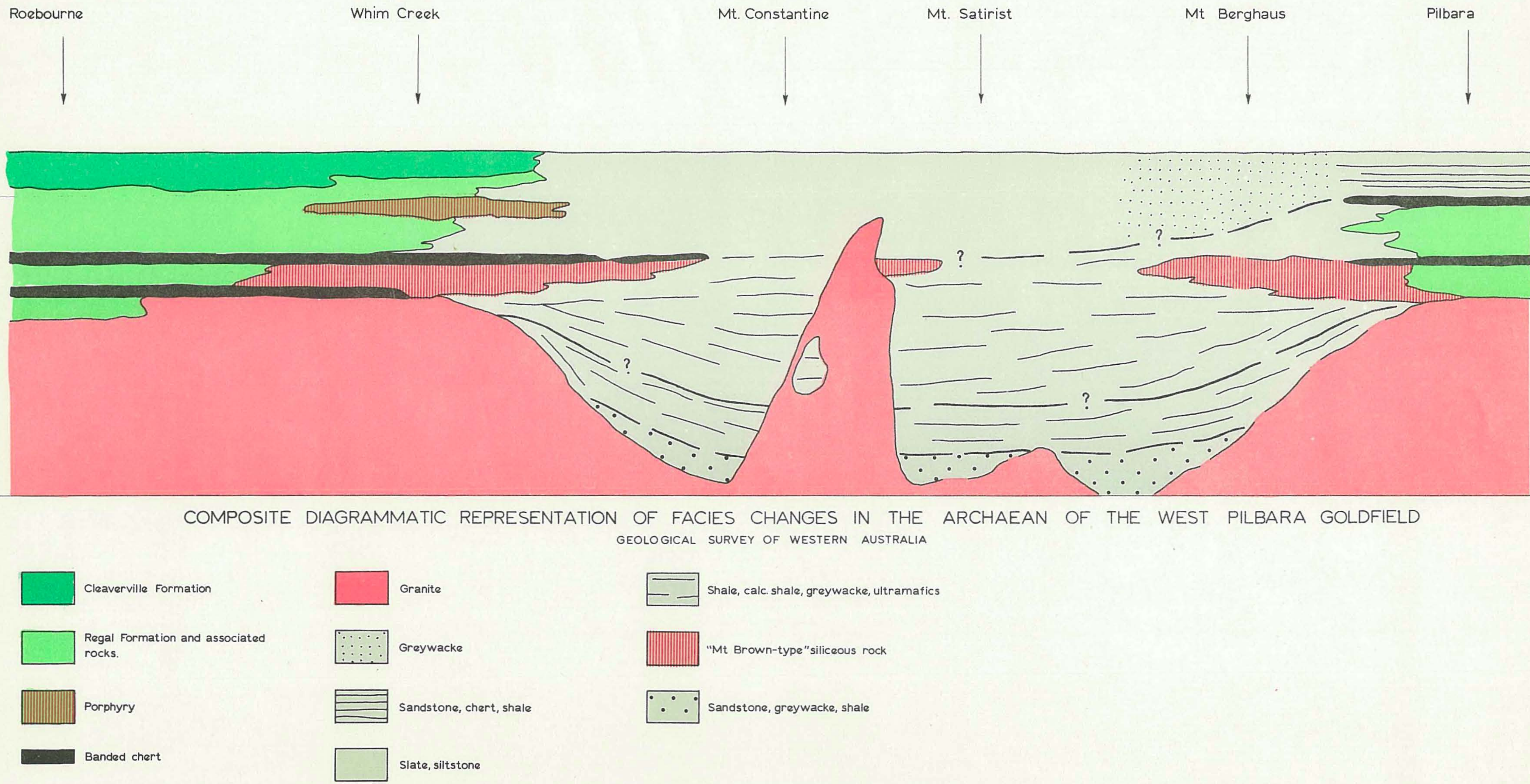
By M. Kriewaldt

ABSTRACT

The Fortescue Group in the Roebourne region is a lower part of the long-established Nullagine Series and is considered to be Lower Proterozoic with an age in excess of 2,000 m.y. The group is amended to include at its base the Mt. Roe Basalt which is formally named and described. Correlations are made with rock units in adjoining areas.

INTRODUCTION

Fortescue Group is a name established by MacLeod and others (1963, pp. 91-93) for an assemblage of Proterozoic volcanic and sedimentary rocks recognised during their 1962 mapping in the Hamersley Range area of the North-West Division of Western Australia. Further information on this group based on field work in 1963 by G. R. Ryan and myself is here summarised, along with a brief appreciation of earlier and concurrent work, the definition of a rock unit at the base of the group, and an amendment to the group. Use is made of mapping in 1963 by L. E. de la Hunty in the Roy Hill 1:250,000 map area. His help is gratefully acknowledged. Petrological examinations of rocks from the area were done by A. F. Trendall, and palaeontological determinations are being made by H. S. Edgell. Stratigraphic names used here without direct reference, at first appearance are taken from "A Preliminary Report on the Hamersley Iron Province, North-West Division" by MacLeod and others (1963). Geographic names are shown on the geological sketch map (Plate 21).



COMPOSITE DIAGRAMMATIC REPRESENTATION OF FACIES CHANGES IN THE ARCHAEAN OF THE WEST PILBARA GOLDFIELD

GEOLOGICAL SURVEY OF WESTERN AUSTRALIA

PLATE 20

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The main feature of the Fortescue Group is its volcanic rocks—basalts and andesites, some amygdaloidal and with agates, some with columnar jointing, and some with pillow lavas. The maximum thickness of the extrusive rocks in the group is estimated at 11,000 feet, but averages nearer 3,000 feet.

During the volcanic activity which formed these extrusive rocks, there were two main intervals of sedimentation: an earlier, having strong pyroclastic activity associated with a large proportion of conglomeratic sedimentation and also a subordinate amount of chemical sedimentation; and a later, more quiescent period with conditions suitable for algal growth, chemical precipitation and sedimentation of fine-grained material. There was some explosive and extrusive volcanic activity during this later time, especially towards the east.

After the volcanic phase of the sequence there followed a stable phase with the deposition of clays, gels and chemical precipitates, with varying environmental conditions in space and time controlling the sedimentation. During this stable phase the upper part of the Fortescue Group and the overlying Hamersley Group was deposited with one further interlude of volcanism.

SURFACE OF UNCONFORMITY

The sequence lies unconformably and transgressively on an Archaean basement. The marked differences in the geology above and below the unconformity and its large areal extent are taken as being indicative of a major break in the sedimentary record in this area. There are irregularities in the surface of unconformity, ranging up to thousands of feet, which can variously be interpreted as indicating the following:—

(1) Basement topographic relief before formation of the Fortescue Group;

(2) Warping and local folding of the basement after the formation of the Fortescue Group;

(3) Faulting and local downwarping contemporaneous with the formation of the Fortescue Group.

The first of these possibilities was suggested by Maitland (1909, p. 118) for the Archaean inlier at Nunyerry. Two examples of abutment unconformities with volcanic rocks abutting against basement ridges have been mapped by G. R. Ryan at Mt. Ada and west of Mt. Anketell in the Roebourne area, and there is another example at Nunyerry Gap. Local folding of the basal contact has been pointed out in the field by R. C. Horwitz in the vicinity of Mt. Wilkie west of Roebourne. The third possibility is considered by G. R. Ryan (pers. comm.) to be strongly supported by field observation near Mt. Roe south of Roebourne. The evidence is that a volcanic unit resting on basement and conformably overlain by a sandstone unit, changes abruptly in thickness from 8,000 feet to 700 feet over a distance of 200 yards.

He has also pointed out the coincidence throughout the Pilbara region of outliers of rocks of the Fortescue Group above Archaean "synclines" and the absence of these rocks over granitic "domes." On the basis of the apparent continuity of tectonism across the unconformity, he considers, further, that there need not have been a long time between the formation of the basement and the deposition of the overlying rocks.

The transgressive nature of the base of the group is shown by the absence of one, two, or three of the lower rock units in various areas. The second unit (clastic and pyroclastic) from the bottom of the group is the basal unit over most of the area, the first unit (volcanic flows, mainly) being more restricted. Towards the east of the Pyramid 1:250,000 map area the basal formation is a basalt, the third unit from the bottom of the group. Further to the east and northeast, for instance in the Nullagine map area, the basal formation is either this volcanic unit or the underlying clastic and pyroclastic unit along with some extrusive volcanic rocks. However, the lower three units are missing in some places in the Balfour Downs map area, the fourth (dolomitic) unit from the base of the group resting on basement, and elsewhere in the Roy Hill Map area this unit is separated from the basement by only a few tens of feet thickness of basalt. Disregarding the lowermost unit, the maximum amount of transgression is 2,000 feet, and adding in the usual thickness of the basal unit, the transgression is around 2,500 feet.

DESCRIPTION

The Fortescue Group of the Roebourne region has been divided into nine chronologically significant map units for publication on maps at the scale of 1:250,000. Within these units, smaller units have been mapped, some of which cover areas large enough to be usefully depicted on the 1:250,000 maps. These smaller units are of two distinct kinds: firstly, lateral facies variations; and secondly, vertically contiguous sub-units of the larger map units. The nine units are briefly described and shown in stratigraphic order with the youngest unit on top in Table 1.

TABLE 1

FORTESCUE GROUP STRATIGRAPHY IN THE ROEBOURNE REGION

Unit	Lithology	Thickness (in feet)
Top		
9	Shale, black when fresh, bleached to white at surface; with marcasite balls	300– 400
8	Shale, dolomite, chert, jaspilite	100– 300
7	Quartzite, sandstone, chert	50– 200
6	Basalt, amygdaloidal; with intercalated chert beds	100– 200
5	Basalt, massive and amygdaloidal	1,000–2,000
4	Shale, dolomite with oolites and pisolites; tuff with lapilli. *Collenia sp.*	150– 500
3	Basalt, massive and amygdaloidal	600– 700
2	Shale, sandstone, conglomerate; tuff and agglomerate with lapilli; dolomite with oolites and pisolites	1,000–2,000
1	Basalt, massive and amygdaloidal	400– 800
Base		
	Total thickness approximately	4,000–7,000

Notes on Table:

(1) Unit 3 is absent to the east of Mt. Herbert.

(2) Unit 1 also ranges up to a thickness of 8,000 feet.

EARLIER AND CONCURRENT WORK

The Fortescue Group in the Roebourne region was mapped as part of the Nullagine Series by earlier workers. (This Nullagine Series subsequently became a widely accepted provincial time-rock unit, commonly taken as being of Late Proterozoic age. See for instance David, 1932, p. 34.) The early mapping of rocks which are now considered to be part of the Fortescue Group was done by A. Gibb Maitland and H. W. B. Talbot between 1903 and 1905, by H. P. Woodward in 1909, and later by Talbot in 1914. In the 1930's geologists and mineral surveyors of the Aerial, Geological and Geophysical Survey of Northern Australia made observations in the vicinity of mining centres in the Pilbara region adding further to the knowledge of the Nullagine Series. More recent work is that of geologists of the Commonwealth Bureau of Mineral Resources, Geology and Geophysics on the southwestern edge of the Canning Basin and of geologists of the Geological Survey of Western Australia throughout the North-West Division. A tentative correlation of units mapped in neighbouring areas is shown in Table 2.

TABLE 2

TENTATIVE CORRELATIONS WITHIN THE FORTESCUE GROUP AND THE OVERLYING FORMATIONS.

Marble Bar, Yarrie and Nullagine map areas	Roebourne and Pyramid map areas	Mt. Bruce map area
CARAWINE DOLOMITE	WITTENOOM DOLOMITE	WITTENOOM DOLOMITE
	MARRA MAMBA IRON FORMATION	MARRA MAMBA IRON FORMATION
	Units 9, 8, 7. Shales, cherts, jaspilites	JEERINAH FORMATION
"upper" LITTLE DE GREY LAVA	Units 6, 5. Basalt	
TUMBIANA PISOLITE	Unit 4. Shale, tuff, dolomite	Bunjinah Member of MT. JOPE BASALT
"lower" LITTLE DE GREY LAVA and "upper" COONGAN VOLCANICS	Unit 3. Basalt	
BEATON CREEK CONGLOMERATE, GREEN HOLE CONGLOMERATE, BUDJAN CREEK FORMATION, GLENHERRING SHALE, "lower" COONGAN VOLCANICS	Unit 2. Clastic and pyroclastic rocks	Pyradie and Boongal members of MT. JOPE BASALT; and HARDEY SANDSTONE
—	Unit 1. Basalt	—

Notes on Table:

(1) The stratigraphic column in the Marble Bar, Yarrie and Nullagine map areas is an interpretation based on the work of Traves and others (1956), de la Hunty (1963), Maitland (1908), Noldart and Wyatt (1962), Ryan (1964).

(2) In the Balfour Downs map area the Lewin Shale lies between the Carawine Dolomite and the Little De Grey Lava. It is a lateral equivalent of the Marra Mamba Iron Formation together with units 7, 8 and 9.

(3) The Tumbiana Pisolite was correlated with the Carawine Dolomite by Noldart and Wyatt (1962, p. 80), and what amounts to the same correlation was made by Maitland and by Talbot. Also the dolomite in the Yarrie map area which appears to be continuous with the Tumbiana Pisolite was correlated with the Carawine Dolomite by Traves and others (1956).

(4) The three members of the Mt. Jope Basalt are named by de la Hunty (in press).

TOP OF GROUP

Regarding the upper limit of the Fortescue Group, the definition of MacLeod and others (1963, p. 46) is that "the upper limit of the group is arbitrarily placed at the base of the Marra Mamba Iron Formation." This placement is followed in the area north of the Fortescue River although a more natural grouping in this area would be to confine the Fortescue Group to the volcanics and the lower intercalated sediments, and to extend the Hamersley Group downwards to the bottom of the Jeerinah Formation equivalent. This is because here the units within the Jeerinah Formation equivalent and the overlying Marra Mamba Iron Formation are all part of a sequence of chemically deposited sediments (dolomites, cherts and jaspilites) with some fine-grained clastic sediments (siltstones and shales); and north of the Fortescue River the Marra Mamba Iron Formation is not the first "thick and persistent iron formation."

MOUNT ROE BASALT—A NEW STRATIGRAPHIC NAME

It is proposed to name a lithostratigraphic unit in the Roebourne region the Mount Roe Basalt, and the unit is described and commented on as follows:—

Rock Types

The unit is volcanic, the main rock types being basalts and andesites. There are also restricted occurrences of agglomerate, local basal arkoses, and local intercalations of shales and ripple-marked quartz sandstones. The volcanics are massive, vesicular, and amygdaloidal with calcite and quartz infillings including agates. There are minor thicknesses of porphyritic basalts with altered feldspar phenocrysts in radiate clusters. The volcanics are flows, with fine-grained contacts, coarser-grained centres and scoriae. Columnar jointing is common. Petrological examination shows some of the volcanic rocks to be fresh, while in others the pyroxenes and felspars are greatly altered.

Selection of Name

The geographical part of the name is taken from Mt. Roe some 11 miles southerly from Roebourne, where there is an easily accessible and typical outcrop of the formation. The lithological part of the name is given for the predominating rock type which is suitably described by the field term basalt.

Distribution

The unit has been mapped in the Roebourne and Pyramid 1:250,000 map areas, and is thought to be present in the Dampier and Yarraloola map areas also.

Type Section

A type section was not measured and described.

Type Area

The type area is from the unconformity north of Mt. Roe to the overlying agglomerate bed at Pinanular Pool. This area is about 12 miles southerly from Roebourne on the Andover and Cooya Pooya road.

Reference Localities

Other features of the formation can be seen at the following reference localities:

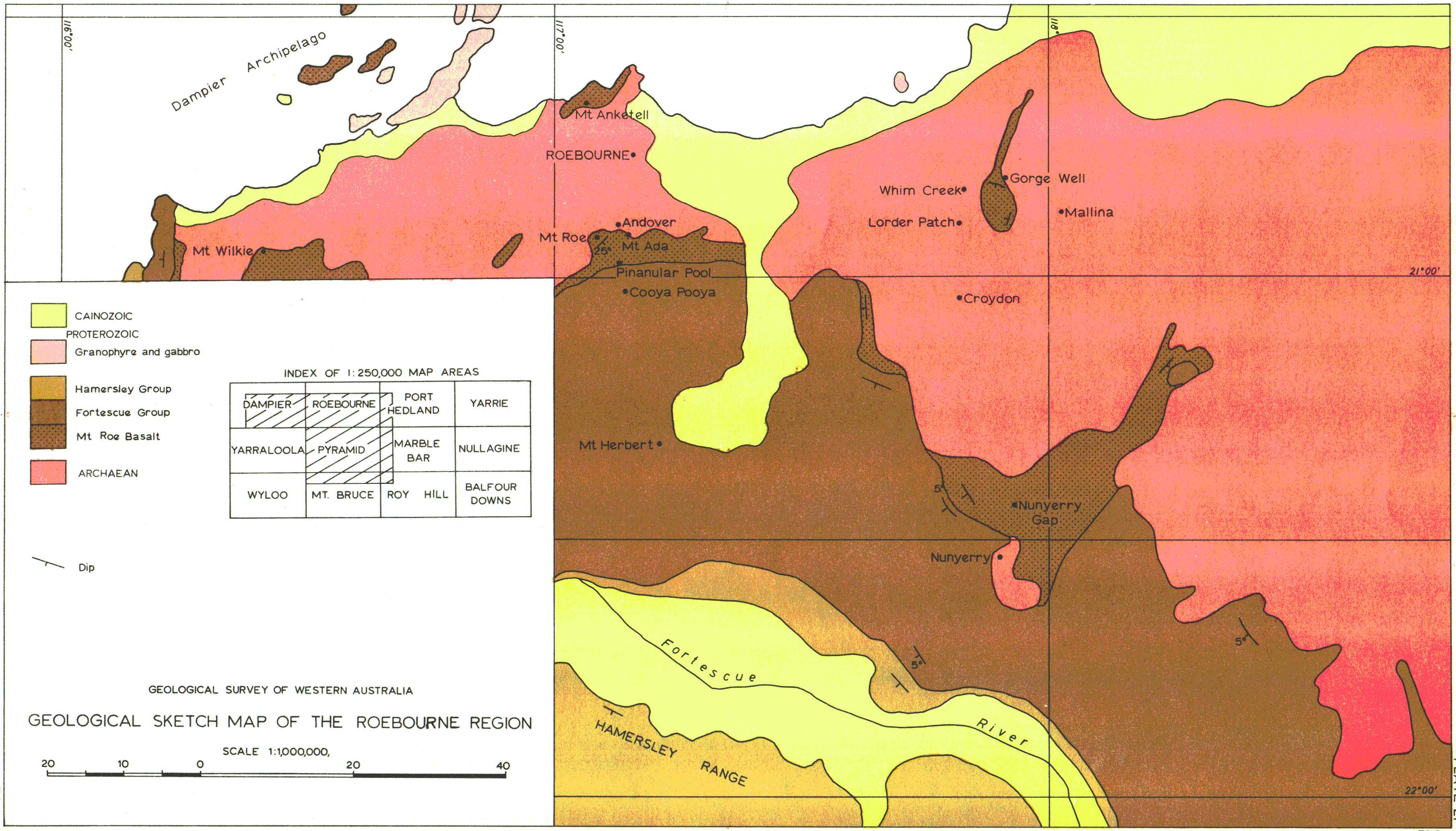
(a) For Agglomerates.
- (i) Westerly from Mt. Anketell, 8 miles northwesterly from Roebourne. Approximately: Latitude 20° 40′ S., Longitude 117° 04′ E.
- (ii) At Lorden Patch, 4 miles southerly from Whim Creek. Approximately: Latitude 20° 54′ S., Longitude 117° 49′ E.

(b) For Porphyritic Rock.
- (i) As for (a) (i).
- (ii) Four miles easterly from Whim Creek on the old Mallina track, 1 mile westerly from Gorge Well. Approximately: Latitude 20° 50′ S., Longitude 117° 54′ E.
- (iii) Seven miles southeasterly from Nunyerry near Kadjebut Spring. Approximately: Latitude 21° 37′ S., Longitude 118° 00′ E.

(c) For main intercalation of sediments. Five miles southeasterly from Whim Creek, east of the Croydon Road. Approximately: Latitude 20° 53′ S., Longitude 117° 53′ E.

Description of Formation in Type Area

In the type area there are several flows of columnar jointed, massive and amygdaloidal basalt, cropping out as hills rising to 600 feet at Mt. Roe. The erosion pattern of the flows which dip southeasterly at 20 degrees is dip slopes to the southeast and stepped benches and scarps to the northwest. At their thickest the lavas total 8,000 feet,



GEOLOGICAL SURVEY OF WESTERN AUSTRALIA

GEOLOGICAL SKETCH MAP OF THE ROEBOURNE REGION

SCALE 1:1,000,000,

PLATE 21

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although southwesterly from Pinanular Pool they are only 700 feet thick. This rapid change in thickness is thought to be caused by subsidence contemporaneous with the extrusion of these lavas. The unconformity between the lavas and the basement is exposed north of Mt. Roe as an angular unconformity, but elsewhere it is not so immediately obvious. The top of the unit is taken at the bottom of an overlying thin bed of boulder agglomerate which is overlain by a micaceous sandstone bed. This relationship can be seen in the vicinity of Pinanular Pool, and to the south of Mt. Ada.

Bottom Boundary

The unconformable contact with the Archaean basement is the bottom boundary of the unit.

Top Boundary

The top of the formation is taken at the contact between the basalt and the overlying sedimentary rocks which are variously shale, sandstone, conglomerate; agglomerate and tuff with lapilli; dolomite with oolites and pisolites.

Recognition of Formation

The formation is recognised primarily on its position at the base of the succession, as neither rock type nor photo-pattern are sufficient to distinguish the formation from units higher in the sequence with similar photo-patterns and rock types. In the case of isolated outcrops the recognition is based less surely on lithology and on the presence of the basal unconformity.

Thickness

The thickness of the Mt. Roe Basalt ranges in general from 400 to 800 feet although exceptionally it is up to 8,000 feet thick.

Shape

Apart from local wedge-shaped thickenings, the Mt. Roe Basalt has a tabular shape. Area of outcrop on the Roebourne and Pyramid map areas covers some 300 square miles, and there is thought to be further outcrop on the Dampier and Yarraloola map areas.

Geomorphology

The geomorphic expression of the Mt. Roe Basalt is mostly bold hills with scarps and dip slopes which correspond to the various flows. The major drainage pattern on the unit is dendritic, although in many instances controlled by jointing giving an angular pattern. The minor drainage pattern is also mainly angular, being controlled by smaller joints.

Photo-pattern

The airphoto pattern of the unit has both smooth and rough textures with two tones of pale grey and some irregular areas of black.

Environment of Formation

It is thought that the lavas of the formation were extruded on a peneplaned land surface having monadnock ridges of chert and jaspilite, and that the volcanism was accompanied by local subsidence, possibly along faults associated with fissure vents feeding the flows. The possibility of fissure vents in the Roebourne area was first pointed out by Woodward (1911, p. 23). The intercalated sediments are considered to be terrestrial shallow-water deposits.

Correlations

Outliers of volcanic rocks which lie unconformably on the basement in the Roebourne area are placed in the Mt. Roe Basalt because of their common lithologies and the common bottom contact, but as the top contact of the unit in these outliers has been eroded away, there must remain some doubt as to their position. Likewise, on the same grounds and with the same qualification, the outliers of volcanic rocks in the Dampier map area are correlated with the Mt. Roe Basalt although previously they have been tentatively correlated with the Mt. Jope Basalt (Kriewaldt, 1964). In particular, the basalts of the Dampier Archipelago are difficult to place, although they are here thought to be part of the Mt. Roe Basalt. Similar volcanic rocks at Mt. Wilkie are overlain by sandstones and arkoses which are in turn overlain by further basalts. Because of this succession the correlation of the bottom basalts with the Mt. Roe Basalt is rather more certain. These rocks continue southwards on to the Yarraloola map area, and mapping of this area should show further Mt. Roe Basalt and settle the position of the basalt at Mt. Wilkie.

Earlier reports indicate that there are basalts in a somewhat similar position in the sequence to the east in the Nullagine map area. Possibly the formation of some of these basalts was coeval with those of the Mt. Roe Basalt, but as it appears that there was no continuity of the basalts as a rock body, a rock-unit correlation of these basalts with the Mt. Roe Basalt is not suggested. Similarly, the more recent work in the Mt. Bruce and Wyloo map areas has shown the presence of basalts within the basal formation of the sequence. Some of these basalts are the lowermost unit exposed, but not necessarily at the base of the sequence. Once again, correlation is not suggested.

Stratigraphic Position

The Mt. Roe Basalt is here included in the Fortescue Group which was proposed by MacLeod and others (1963, p. 46) for the lower part of a larger rock unit previously described and called the Nullagine Series (Maitland, 1908, p. 120-130; 1909, p. 116-123). It is included because it conformably underlies a sequence which is part of the Fortescue Group and because the basalts of the formation are similar to those of the overlying formations. In particular, rocks identical with the distinctive porphyritic basalts which are present in the Mt. Roe Basalt are also present in higher formations. Its stratigraphic position is considered to be below any of the Fortescue Group in the type area, but this is not certain as the exact equivalence of the succession in the type area and in the area of outcrop of the Mt. Roe Basalt is unknown. Briefly the reason for placing the formation at the base of the group is that the lowermost formation (Hardey Sandstone) of the Fortescue Group in the type area is a sandstone with some intercalated basalt and agglomerate, and the lowermost sedimentary unit with associated volcanic rocks in the Pyramid and Roebourne map areas is the unit which immediately overlies the Mt. Roe Basalt. Equating these two rock units as being (in part at least) spatial equivalents in the succession, the Mt. Roe Basalt lies either totally below the Hardey Sandstone or is wholly or partly a lateral spatial equivalent of part of it. As indicated, the first alternative is favoured.

Age

There is at present no age determination on material from the Mt. Roe Basalt. A sample of basalt from southwest of Mt. Wilkie immediately above the Archaean basement has been submitted for determination. This basalt is thought to be part of the Mt. Roe Basalt.

Some 2,000 feet higher in the succession than the top of the Mt. Roe Basalt there are fossils identified as *Collenia sp.* by H. S. Edgell who is examining them further. He considers that an algal assemblage from much higher in the succession (from the Duck Creek Dolomite) is indicative of a Middle Proterozoic age (Edgell, 1962). It follows that the Mt. Roe Basalt must be at least as old as Middle Proterozoic.

Previously this unit has been included (Maitland, 1909, plate X; Woodward, 1911, p. 21) in the Nullagine Series which has since become a generally accepted provincial time-rock unit for the Upper Proterozoic of Western Australia. (See for instance David, 1932, p. 34; Clarke and others, 1962, p. 224; although Hossfeld 1954, p. 127, has suggested Middle Proterozoic and the rocks are indicated as undifferentiated Proterzoic on the Tectonic Map of Australia, 1960). Recent mapping by J. Daniels, L. E. de la Hunty, R. Halligan, W. R. Jones and W. N. MacLeod makes a Late Proterozoic age untenable for these rocks, as does also unpublished information on age determination on rocks higher in the succession, a preliminary assessment of the results indicating ages around 2,000 million years. An Early Proterozoic age for the Nullagine Series has been suggested also by J. Sofoulis (1962, p. 18) on geotectonic grounds.

Economic Geology

Agates are plentiful in parts of the formation and have been eroded out to form deposits of agates on the slopes and plains near the outcrops. The commercial possibilities of the agates and other stones in the district was pointed out by H. P. Woodward in 1888 (Woodward, 1890, p. 35), but until recently there has been practically no exploitation. Now a small quantity of agate derived from Mt. Roe Basalt and other amygdaloidal basalts in the Roebourne region is being collected and sold.

Most of the outcrop of the formation is too rugged and bare for grazing, only spinifex growing on what little soil there is.

Apart from one or two wells, the formation has not been utilised for underground water as there are more readily available supplies in nearby areas.

AMENDMENT OF THE FORTESCUE GROUP

The Fortescue Group is here amended to the extent of including the Mt. Roe Basalt at the bottom of the group for reasons outlined in the description of the Mt. Roe Basalt.

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IRON ORE DEPOSITS IN THE EASTERN SECTION OF THE HAMERSLEY IRON PROVINCE

By W. N. MacLeod

ABSTRACT

High-grade hematite deposits are abundant in the eastern section of the Hamersley Iron Province. The largest deposits occur in the Weeli Wolli Spring and Ophthalmia Range areas where the combined inferred reserves have been estimated to exceed 50 million tons per foot depth. Most of the ore zones are between 50 and 100 feet thick but localised thicknesses in excess of 300 feet have been recorded. The range in grade of the hematite ore is between 55 and 69 per cent. iron. The Proterozoic sediments of the Hamersley and Fortescue Groups differ little in thickness or lithology from their equivalents in the central and western parts of the iron province.

INTRODUCTION

During the 1963 field season the Geological Survey completed the mapping of the Hamersley Iron Province with particular attention to the eastern and southern sections of the province. Mapping was mainly confined to the Roy Hill, Newman, Turee Creek and Robertson 1:250,000 sheets.

There are two zones within this section of the iron province where exceptional concentrations of hematite have been recognised. These are near Mt. Newman Station, along the southern flank of the Ophthalmia Range; and in the country around Weeli Wolli Spring, near the easternmost extremity of the Hamersley Range. The great potential of these two areas was first recognised by Mr. A. S. Hilditch who scout prospected both areas in the summer of 1961/62. In recent months the iron ore deposits have been systematically examined by the United States Metal Refining Co., a wholly owned subsidiary of American Metal Climax. Personnel of the Geological Survey have co-operated with the company in this exploration programme. The following report outlines the stratigraphy, structure and iron ore distribution within this section of the province and may be regarded as supplementary to an earlier report by MacLeod, de la Hunty, Jones and Halligan (1963).

REGIONAL GEOLOGY

Stratigraphy and Structure

The sedimentary and volcanic rocks of the Proterozoic Fortescue and Hamersley Groups (MacLeod and others, 1963; de la Hunty, in press) are the principal geological components of the eastern section of the Hamersley Iron Province. The stratigraphic units established from the mapping of the Mt. Bruce, Yarraloola and Wyloo Sheets continue eastwards with only minor changes in lithology or thickness.

The most significant differences in the succession are the virtual disappearance of the thick volcanic and pyroclastic units of the Fortescue Group. In the Ophthalmia Range the group is represented by shale intruded by thick dolerite sills. This basal unit corresponds to the Jeerinah Formation of the Mt. Bruce Sheet and has been mapped as such. The Marra Mamba, Brockman and Boolgeeda Iron Formations appear to be unchanged. The Weeli Wolli Formation, which conformably overlies the Brockman Iron Formation, is much better exposed in the eastern section of the province and its lithology has been more accurately defined. The Woongarra Dacite, which is about 1,600 feet thick in the Mt. Brockman Syncline, is of the order of 1,000 feet in the Ophthalmia Range but contains the same rock types.

The sediments and volcanics are strongly folded on east-west axes and the intensity of folding is greatest along the southern front of the Ophthalmia Range. Here the folding is almost isoclinal and there is some overturning of beds near the Archaean nucleus. The folds are of low amplitude and gently plunging with frequent reversals in plunge direction. This has produced a repetition of elliptical domes and basins with long axes aligned parallel to the eastwest trending fold axes.

The east-west folds are transected by north-east-trending gravity faults some of which must have vertical displacements measurable in thousands of feet. The faulting may have been partly contemporaneous with the folding, but for the greater part is considered to be later.

The stratigraphic succession in the Ophthalmia Range is summarised in the following table:

Era	Group	Formation	Lithology	Thickness (feet)
PROTEROZOIC	Hamersley	Boolgeeda Iron Formation	Jaspilite, ferruginous shale, chert and argillite	700
		Woongarra Dacite....	Acid lava and tuffs	1,000
		Weeli Wolli Formation	Ferruginous shale, jaspilite and dolerite	1,200
		Brockman Iron Formation	Jaspilite, chert and ferroan dolomite	2,000
		McRae Shale	Shale, chert and argillite	200
		Mt. Sylvia Formation	Jaspilite and shale	100
		Wittenoom Dolomite	Dolomite, chert and dolomitic shale	500
		Marra Mamba Iron Formation	Jaspilite and chert	600
	Fortescue	Jeerinah Formation	Shale, phyllite, quartzite with dolerite intrusions	+ 2,000
		- UNCONFORMITY -		
ARCHAEAN		Granite, jaspilite and metasediments		

The strong folding accompanied by complicated puckering and drag folding on the limbs of the major folds renders precise measurements of thickness impossible. The above figures are obtained from measurements of width of outcrop and average dip and could be greater than the true thickness. The Wyloo Group, which conformably overlies the Boolgeeda Iron Formation of the Hamersley Group, is nowhere exposed in the Ophthalmia Range. The one area where it could be expected to appear, within the deep structural trough of the Kalgan Creek Syncline, is overlain by deep alluvium and flood plain detritus of the Fortescue River.

At the easternmost extension of the Hamersley Group, some 10 miles east of the Great Northern Highway, the iron formations are seen to be unconformably overlain by younger Proterozoic sediments of the Bangemall Group. To the south the Hamersley Group is conformably overlain by the Wyloo Group which in turn is unconformably overlain by the younger Bresnahan Group (Daniels and Halligan, 1964).

IRON ORE DEPOSITS

In the Hamersley Iron Province high-grade hematite deposits have resulted from the selective leaching of silica from banded iron formations. This process has operated with greatest efficiency where remnants of the Brockman Iron Formation have been preserved in synclinal troughs and the thickness of erosion residuals of iron formation is less than 300 feet. The ore is developed by supergene processes and is essentially a surficial enrichment of the parent iron formation close to the Tertiary land surface.

The importance of synclinal troughs in ore formation was early recognised in the Hamersley Province and excellent examples of this structural control have been seen in the Mt. Brockman and Mt. Turner synclines in the central area of the province. Photogeological examination of the structure of the Ophthalmia Range indicated a multiplicity of potentially favourable ore zones and mineralisation of many of these was subsequently confirmed by field examination. In zones where the Brockman Iron Formation is not folded, or where a great depth of the formation underlies the old land surface, hematite development is patchy and sporadic and large continuous ore bodies do not exist.

The riverine, pisolitic goethite ores are present in the eastern Hamersley and Ophthalmia Ranges but are developed to a much lesser degree than in the western section of the iron province. As a result of strong folding in a zone in the eastern Ophthalmia Range the outcrop area of the Brockman Iron Formation is much reduced and accordingly the proportion of jaspilite detritus, from which the pisolitic ore is derived, is reduced and diluted. The pisolitic ore is only formed to a significant degree in the broad synclinal basin of Yandicoogina Creek which has been largely infilled with jaspilitic detritus. In Mindy Mindy and Coondiner Creeks, pisolitic and conglomeratic ores are only preserved as terraces along the gorge walls, much of the material having been scoured away by vigorous erosion.

There are two zones within the eastern section of the iron province where there is a prolific development of hematite. These are in the vicinity of Weeli Wolli Spring and along the southern front of the Ophthalmia Range near Mt. Newman. Reserves of ore, calculated on the basis of outcrop area, exceed 50 million tons per foot depth. In many of the deposits the thickness of the ore is greater than 100 feet as exposed in natural sections.

Hematite Deposits of the Weeli Wolli Anticline

The hematite deposits near Weeli Wolli Spring were discovered by Mr. A. S. Hilditch during the summer of 1961-62, and briefly examined by the writer, in company with Mr. Hilditch, in September, 1962. The area was mapped in some detail by the writer in May, 1963, and re-visited in October, 1963, in company with geologists of the United States Metal Refining Co. who had chartered a helicopter for iron ore exploration. A thorough examination of the area disclosed a tremendous potential of iron ore totalling about 40 million tons per foot distributed among about 40 separate ore zones.

The major structural unit is an elliptical anticlinal dome measuring 50 miles along the east-west axis and about 10 miles wide. The eastern end of the anticline plunges at about 5 degrees to the east and there is a similar low plunge to the west at the western end of the structure. There are persistent flexure belts within the main structure which continue for many miles and it is within the minor synclinal folds in these flexure zones that the hematite ores are best developed, (see Plate 22).

The most prolific development of hematite is along a monoclinal flexure within the Brockman Iron Formation in the northern limb of the major anticline. Over 20 separate ore zones have been discovered in this belt over a distance of nearly 50 miles. Another rich zone is at the strongly flexured eastern end of the structure where the basal zone of the Brockman Iron Formation is repetitively preserved in a succession of parallel synclinal troughs. There is, in addition, a strong development of hematite in the complementary synclinal trough on the southern side of the Weeli Wolli Anticline. The core of the major anticline is occupied by the Marra Mamba Iron Formation. This too is strongly flexured and shows a minor amount of hematite.

On the northern side of the Weeli Wolli Anticline the Brockman Iron Formation has a gentle regional dip to the north and disappears beneath the ferruginous shales and dolerite of the Weeli Wolli Formation. On the southern side, the Brockman Iron Formation has been removed by erosion on the southern side of the Mt. Robinson Syncline and does not reappear until the core of the next major syncline at Giles Point in the western Ophthalmia Range.

The dominant structural control of ore formation along the northern limb of the Weeli Wolli Anticline is a persistent monoclinal warp in the Brockman Iron Formation. Within this warp there are strong minor folds which vary in intensity along the axis of the warp. Immediately west of the Weeli Wolli Spring there are two well defined synclinal troughs within the major monoclinal structure and these serve as important loci for hematite. These troughs converge and die out 4½ miles west of the springs but reappear at a point a further 5 miles west and continue with parallel trends for 15 miles. East of the spring the minor folds are not so clearly defined and the ore is developed within a strongly crenulated zone within the steeply dipping limb of the monocline. It is possible that there has been some strike faulting in this eastern zone to produce a repetition of the basal zone of the Brockman Iron Formation.

The hematite deposit immediately west of Weeli Wolli Spring contains a high proportion of massive blue ore and has been shown to extend almost continuously for nearly 3 miles. Reserves in this deposit are estimated to amount to over 2 million tons per foot depth. The deposit is at low elevation and readily accessible. East of the spring the hematite zone, although comparatively narrow, extends continuously for 4 miles and also contains a high proportion of massive or coarsely banded blue ore of high grade. Reserves in this zone amount to about 1.5 million tons per foot without taking account of the large quantities of high-grade scree ore which mantle the lower slopes of the range. Drilling has established that some of the ore near Weeli Wolli Spring has a high manganese content at depth.

Southeast of Weeli Wolli one passes into a zone of stronger folding within the nose of the major Weeli Wolli anticline. Here the base of the Brockman Iron Formation repetitively appears as erosion residuals in the cores of easterly plunging synclines and hematite is developed within each of these structures. As is common, there is intense minor folding of the iron formation within these synclines and conditions appear to have been ideal for the enrichment of the jaspilite by selective removal of silica. This folded zone exhibits the most spectacular continuous development of hematite yet encountered within the Hamersley Iron Province. The basal zone of the Brockman Iron Formation can be followed with only minor breaks for 17 miles around the fold convolutions and has been converted to hematite over practically the whole of this distance. The quality and depth of the hematite vary considerably, but the zone must contain many hundreds of millions of tons of ore.

The southern boundary of the Weeli Wolli anticline is marked by the prominent east-west range, situated 9 miles south of Weeli Wolli Spring. This range represents the core of the complementary syncline termed the Mt. Robinson Syncline, and is capped by residuals of Brockman Iron Formation along the greater part of its length of 9 miles. Most of these Brockman residuals have been transformed to hematite, and the large deposit near the eastern end of the range is estimated to contain about 2 million tons per foot, and in places is seen to be at least 150 feet thick. Mt. Robinson, which forms a prominent hill mass some 8 miles further west along the axis of the same synclinal fold is also capped with Brockman Iron Formation but is comparatively poor in hematite.

There are numerous hematite occurrences in the country between Mt. Newman and Weeli Wolli Creek particularly along the range forming the eastern extension of the Mt. Robinson Syncline, and further south in Pamelia Hill which represents the core of the next major syncline to the south.

Assays of some typical ore samples from the Weeli Wolli area are tabulated below:

TABLE 1.

ANALYSES OF IRON ORE FROM WEELI WOLLI AREA

Sample No.	4675	4676	8091	4661
	%	%	%	%
Fe (Acid Soluble)	65·9	64·2	64·4	60·5
SiO_2	0·88	2·16	1·82	4·24
Al_2O_3	0·89	1·52	0·79	2·72
P	0·06	0·07	0·08	0·07
S	0·02	0·05	0·05	0·07
TiO_2	0·09	0·02	0·02	0·27
Mn	0·03	0·06	0·02	0·07
Cu	0·002	0·002	0·004	0·002
H_2O+	3·82	4·25	5·33	5·21

4675—Massive hematite-geothite ore, Weeli Wolli Spring.
4676—Platy hematite-goethite ore, Weeli Wolli Spring.
8091—Hematite-geothite ore, 20 miles W. of Weeli Wolli Spring.
4661—Hematite conglomerate, Coondiner Creek.

Hematite Deposits of the Mt. Newman Area

The structural pattern of the Ophthàlmia Range in the Mt. Newman Area is much more complex than that of Weeli Wolli. Folding is stronger, particularly in the axial zones of the major folds, and the area has been much disturbed by faulting. As at Weeli Wolli, synclinal cores are favoured loci for hematite enrichment of the iron formations. In addition, it is apparent that the iron formations have in places been severely contorted and drag folded near the larger faults and these disturbed zones have been favourable to enrichment. Such a zone exists along the southern flank of the Ophthalmia Range, eastwards from Mt. Newman, and carries many large deposits of high grade hematite (see Plate 23).

The extensive Archaean nucleus south of the Ophthalmia Range is flanked on the north by strongly folded and overturned sediments of the Fortescue and Hamersley Groups and overlain on the southern and eastern sides by younger Proterozoic sediments of the Bangemall Group which are virtually undisturbed. It would appear that this nucleus may represent a focal point of regional upwarping during the period when the Hamersley Group was folded and that the sediments closest to this nucleus have been most disturbed. In the Fortescue River Valley, the Hamersley sediments and volcanics are overturned for distances up to 8 miles north of the unconformity and it is this zone which has been most severely faulted. Similar but less intense zones of tectonic disturbance are found in the Hamersley and Fortescue sediments around the perimeters of the Rocklea and Milli Milli Archaean nuclei in the central section of the iron province.

The first hematite ore body to attract attention in the Mt. Newman area was that of Mt. Whaleback, situated 4 miles southwest of Mt. Newman Homestead. This deposit has been examined in detail by U.S. Metal Refining Co. who commenced a programme of drilling and detailed mapping in October, 1963. Mt. Whaleback is a high isolated ridge rising to as much as 800 feet above the general level of the surrounding country and extending for 3½ miles with a northeast trend. The smoothly domed summit ridge is a remnant of the old Tertiary land surface but this surface is much dissected and the flanks of the hill deeply gullied. The distribution of hematite ore is, as usual, directly related to the old land surface and is developed beneath this surface in the Brockman Iron Formation almost continuously for over

GEOLOGICAL SURVEY OF WESTERN AUSTRALIA

GEOLOGICAL SKETCH MAP OF

WEELI WOLLI AREA
HAMERSLEY RANGE

Geology by W. N. MacLeod

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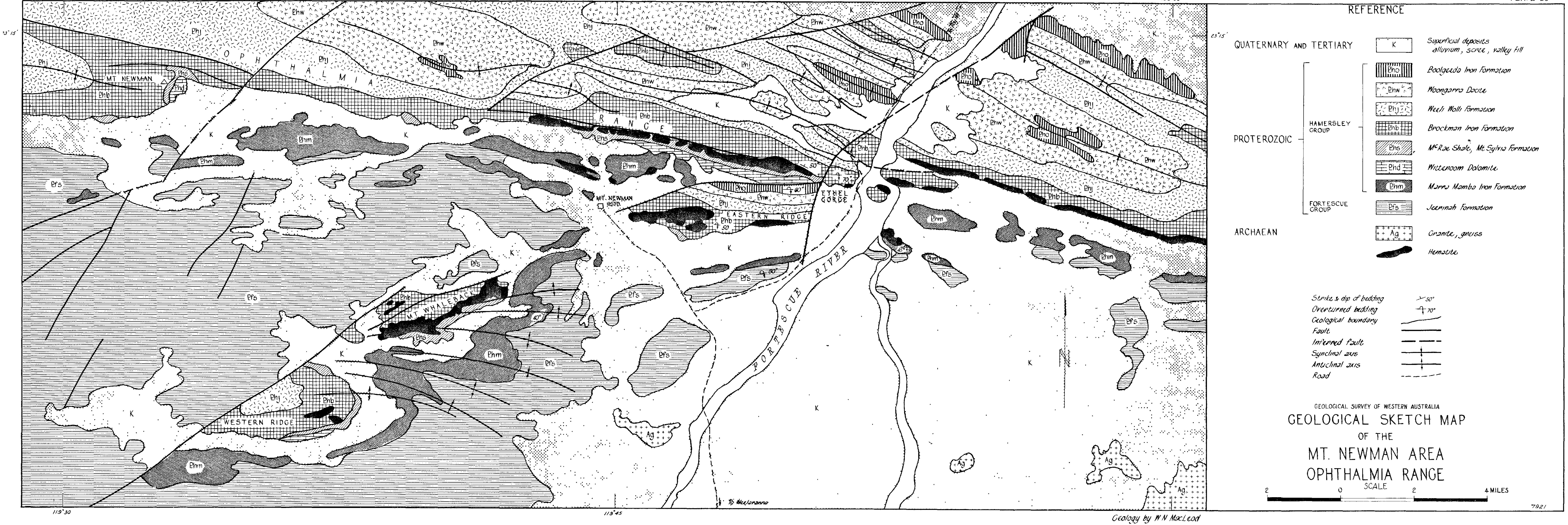
PLATE 23



Geology by W.N. MacLeod

3 miles along the southern side of the summit ridge. Owing to the deep dissection on the flanks of the hill many excellent natural sections of the ore are available for examination. The deposit provides a good example of how large bodies of hematite are formed only within the basal zones of the Brockman Iron Formation when there is an erosion residual of this formation less than 300 feet thick.

At Mt. Whaleback the Brockman Iron Formation occupies the core of a northeast-trending syncline. The western limb of the fold has been faulted out and the Brockman Iron Formation downthrown against the shale of the lower part of the Jeerinah Formation. The outline of the major northeast fold has been blurred by a series of tight east-west trending cross folds which converge with the trend of both the major fold and the large fault on the northern side of the Mt. Whaleback ridge. All units of the succession are violently contorted and this is particularly exemplified by the Brockman Iron Formation in the core of the syncline where the intricate fold convolutions can be followed down to hand specimen size.

The complex folding in the core of the syncline has important economic consequences. The contact between the Brockman Iron Formation and the underlying McRae Shale, which marks the lower limit of hematite, is highly irregular with a rapid alternation of troughs and domes. A deep trough near the northeastern end of the deposit contains high-grade hematite to a depth exceeding 500 feet. This is the greatest thickness of hematite yet recorded in the Hamersley Iron Province. Over anticlines the McRae Shale is high and the amount of hematite between the top of the shale and the surface correspondingly reduced. In places erosion has cut through to the McRae Shale along anticlinal axes and deep troughs have been incised in the summit ridge parallel to the long axis of the hill. The result of this has been to cut the ore into semi-detached segments often separated by deep gullies. The rapid variations in the thickness of the ore necessitates very close drilling for the blocking out of reserves, and the deep dissection of parts of the deposit creates problems of access and greatly increases assessment costs.

In surface exposures most of the ore is a hard, blue, massive hematite with localised zones rich in goethite. Surface assays grade between 64 and 68 per cent. iron and these high grades have been found to continue in depth with occasional admixture of lower grade goethitic and siliceous ore. On the basis of area of outcrop, reserves have been estimated to amount to 1.90 million tons per foot. Due to the great irregularities of the base of the deposit the mineable reserves would be much less than this, but even if reduced by half the Mt. Whaleback deposit would still be ranked with the largest high-grade deposits in the State. Much of the ore is similar in grade and texture to that of the Mt. Tom Price deposit in the central part of the Hamersley Iron Province.

The greater part of the iron ore reserves in the Mt. Newman area are to be found along the southern flank of the Ophthalmia Range from a point almost directly north of Mt. Newman Homestead to Shovellana Hill which lies about 20 miles to the east. Hematite is developed in the Brockman Iron Formation almost continuously along the front of the range in a persistent zone of strong flexuring which is apparently related to a major strike fault. Along the front of the range, which actually is an erosion scarp determined by the resistant Brockman Iron Formation, the sediments have a general steep regional dip to the north with some overturning near the Fortescue River. Strike faulting has caused a repetition of the basal zone of the Brockman Iron Formation and it is in the slivers of iron formation on the southern side of the fault that the maximum amount of ore has been developed. Within this zone the Brockman Iron Formation is strongly contorted on the southern side of the fault and comparatively undisturbed on the northern side. It is in the folded zones that the hematite is most abundantly and continuously developed. Erosion has dissected the scarp face leaving mesaform remnants of the Brockman Iron Formation which cap the McRae Shale and which are largely converted to hematite, in places to depths of nearly 200 feet. On the basis of outcrop area the inferred reserves of hematite in the front of the Ophthalmia Range have been estimated to amount to 7.5 million tons per foot, most of which would be mineable. The deposits are at lower level than at Mt. Whaleback and more accessible. An adequate water supply is available from the thick alluvium and calcrete deposits on the Fortescue River to provide for a large scale mining operation.

In surface exposures the ore is more variable in appearance and grade than that of Mt. Whaleback. There are some zones largely composed of banded platy ore with a high goethite and limonite content. In other zones the ore is more massive with a higher proportion of hard hematite. In general the ore is more typical of that in other areas of the iron province with a probable overall mining grade of 60 to 63 per cent. A small zone of high-grade premium ore occurs on the western side of Ethel Gorge, and there is an extensive high grade deposit near Shovellana Hill.

Further hematite deposits occur in Eastern Ridge, close to Mt. Newman Homestead. This ridge is mainly composed of Brockman Iron Formation which here is overturned to the north and isolated from the main Ophthalmia Range by strike faulting. Hematite is developed along the southern flank of the ridge and the most attractive looking deposits would appear to be those near the central and eastern sections of the hill. At the western end the ore is thin and contains abundant beds of unleached jaspilite.

There are several hematite occurrences on the Western Ridge which lies about 4 miles southwest of Mt. Whaleback. The extent of these deposits, which are developed on the eastern side of the range, is hard to gauge due to thick mantle of hematite scree and canga ore. The Western Ridge is an east-west trending syncline which is obliquely terminated by the Mt. Whaleback fault. The core of the syncline is occupied by jaspilite and dolerite of the Weeli Wolli Formation.

There are numerous showings of hematite in the Marra Mamba Iron Formation in the Mt. Newman area. As is common with hematite bodies in this formation many of the deposits are probably thin and rich in residual chert. The most promising looking deposit in this formation is that in the so-called Homestead Ridge which is situated about half a mile north of the Homestead and extends westward for several miles. Hematite is developed almost continuously along the crest of the ridge and in surface exposures appears to be of good grade. Hematite is common in the Marra Mamba Iron Formation east of the Fortescue River and some of these deposits appear to be of excellent quality. In general the hematite in the Marra Mamba Iron Formation is less obviously banded than that of the Brockman Iron Formation and is finer grained with a tendency towards conchoidal fracture. In addition it has a distinctive greenish hue in bright sunlight. Skins of manganese oxides are more common than on Brockman hematite. An analysis of hematite from the Marra Mamba Iron Formation is quoted in Table 2, together with assays of other typical ore samples from the Mt. Newman area.

TABLE 2.

ANALYSES OF IRON ORE FROM THE MT. NEWMAN AREA

Sample No.	4657	4658	4670	4671	4678
	%	%	%	%	%
Fe (Acid Soluble)	69·1	67·0	67·3	68·1	64·4
SiO_2	0·53	0·94	0·68	0·49	2·27
Al_2O_3	0·10	0·18	0·24	0·13	1·48
P	0·02	Trace	0·06	0·01	0·07
S	0·01	0·01	0·02	Trace	0·08
TiO_2	0·02	0·03	0·01	0·01	0·09
Mn	0·02	0·01	0·02	0·02	0·03
Cu	0·003	0·005	0·002	0·002	0·003
H_2O+	0·52	3·15	2·51	2·19	3·41

4657—Massive hematite, Ethel Gorge, Fortescue River.
4568—Massive hematite, Marra Mamba Iron Formation, 1 mile S. of Ethel Gorge.
4670—Massive hematite, 1½ miles W. of Ethel Gorge, Fortescue River.
4671—Massive hematite, 2 miles N. of Mt. Newman Homestead.
4678—Platy hematite, Boolgeeda Iron Formation, Kalgan Creek.

CONCLUSIONS

Although iron deposits of various types are known to occur over the entire extent of the Hamersley Iron Province it is now clear that there are four zones in which exceptional concentrations of hematite have developed. From west to east these are:

(1) The north and south limbs of the Mt. Brockman syncline.

(2) The Mt. Turner syncline.

(3) The Weeli Wolli anticline.

(4) The southern flank of the Ophthalmia Range.

These groups of deposits are all associated with zones of moderate to strong regional folding and the largest ore deposits are related to the presence of persistent minor fold systems within the limbs of the major regional folds. All significant ore deposits are confined to the basal zone of the Brockman Iron Formation. Most ore zones are between 50 and 150 feet thick and some have been known to exceed 500 feet. The cumulative hematite resources of the region are estimated to be of the order of 90 million tons per foot of depth and most of this ore grades better than 60 per cent. iron.

Although considerable variations in texture, mineralogy and grade of hematite ore are apparent in any one zone and even within individual deposits, there does not appear to be any systematic pattern of overall variation in these characteristics. From the work that has been done it is clear that certain deposits could produce superior mineable grades of ore, several per cent. richer in iron and lower in phosphorus than the average. Such deposits are rare and, with one or two exceptions, limited in size. The striking feature of the province is rather the remarkable consistency of ore type and grade. For a potential major supplier of high grade ore for world markets this is an admirable characteristic.

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PRECAMBRIAN GEOLOGY OF THE ASHBURTON VALLEY REGION, NORTH-WEST DIVISION

By R. Halligan and J. L. Daniels

ABSTRACT

The report describes the geology of the Archaean and Proterozoic rocks of about 17,000 square miles of country, most of which is within the drainage basin of the Ashburton River.

The Proterozoic succession is divided into three main units, the Mt. Bruce Supergroup, the Bresnahan Group and the Bangemall Group.

Four periods of folding affecting these rocks have been recognised.

INTRODUCTION

The area described includes the whole of the Turee Creek and Newman 1:250,000 Map Sheets and part of the Wyloo 1:250,000 Sheet (see Plate 26). Approximately 17,000 square miles is represented most of which is within the drainage basin of the Ashburton River. A broad division into three topographic units is possible, viz., the Hamersley and Ophthalmia Ranges in the north, the Ashburton Valley in the centre, and the Kenneth and Godfrey Ranges in the South. These units correspond closely to the main geological units, i.e., the Hamersley Group, the Wyloo Group and the Bangemall Group.

Access is poor over most of the area. Apart from the main Onslow—Mt. Stuart—Ashburton Downs—Mt. Vernon road, the only motorable tracks are station roads and mill tracks and these are scarce in the more elevated, undeveloped areas.

Most of the watercourses are dry for most of the year, and in the dry season the larger rivers break up into pools.

PREVIOUS WORK

In 1890 H. P. Woodward is reported to have visited mining centres in the Ashburton Valley region, but the first geological traverses were made in this area by A. Gibb Maitland in 1907. He was responsible for naming the Ashburton Beds (1909) and later tentatively correlated them with the Mosquito Creek Series (1919). Later, Talbot (1926) visited the area and correlated the conglomerates at Mt. Bresnahan with the Nullagine Conglomerate because they lie unconformably upon the Ashburton Beds, which were at that time considered to be Archaean.

Probably all of the major subdivisions of the Proterozoic in the North-West Division were visited either by Maitland or Talbot and until recently theirs was the only work available. Since 1962 a large amount of new data has become available and the region has been mapped systematically, with the result that some of Maitland's and Talbot's tentative correlations have been disproved.

In 1962 parts of the area were examined by MacLeod, de la Hunty, Jones and Halligan in the course of an investigation of the iron ore deposits of the Hamersley Iron Province. An account of their work is given in the Annual Report of the Geological Survey of Western Australia for 1962. This survey laid the foundations for the present study.

Geologists of B.H.P. Co. Ltd., Hamersley Iron Pty. Ltd., Westfield Minerals Inc. and U.S. Metal Refining Co. Ltd., have worked in the area during 1963 and their co-operation is gratefully acknowledged.

STRATIGRAPHY—GENERAL

The stratigraphic succession, as developed in the Ashburton Valley, is given in Table 1.

A description of the Fortescue and Hamersley Groups has been given by MacLeod and others (1963) and is also included in Mt. Bruce, W.A. 1:250,000 Geological Series, Explanatory Notes (de la Hunty, in press). The Wyloo Group was partially described in the above studies, but both the Bresnahan and Bangemall Groups are described here for the first time.

TABLE 1.

STRATIGRAPHIC COLUMN

PROTEROZOIC		Bangemall Group	Kurabuka Formation.	
			Fords Creek Shale.	
			Top Camp Dolomite.	
			—unconformity—	
		Bresnahan Group	Kunderong Sandstone.	
			Cherrybooka Conglomerate.	
			—unconformity—	
	Mt. Bruce Supergroup	Wyloo Group	Ashburton Formation.	
			Duck Creek Dolomite.	
			Mt. McGrath Formation	Karlathundra Conglomerate Member.
				Coolbye Shale Member.
				Cheela Springs Basalt Member.
				Nummana Member.
			Beasley River Quartzite.	
			Turee Creek Formation.	
		Hamersley Group	Boolgeeda Iron Formation.	
			Woongarra Volcanics.	
			Weeli Wolli Formation.	
			Brockman Iron Formation.	
			McRae Shale.	
			Mt. Sylvia Formation.	
			Wittenoom Dolomite.	
			Marra Mamba Iron Formation.	
		Fortescue Group	Jeerinah Formation.	
			Mt. Jope Basalt	Bunjinah Pillow Lava Member.
				Pyradie Pyroclastic Member
				Boongal Pillow Lava Member.
			Hardey Sandstone.	
			—unconformity—	
ARCHAEAN	Granites, granite gneiss, basalt, dolerite, serpentinite, jaspilite and quartzite.			

ARCHAEAN

No absolute age or age range is available for the 1,350 square miles of granite, metasediment, basalt and serpentinite cropping out in the eastern central portion of the Newman 1:250,000 Sheet. This association is unconformably overlain by the Mt. Bruce Supergroup, the oldest known Proterozoic rocks in the region, and is consequently referred to the Archaean.

The area consists largely of a wide variety of granites and related rocks carrying relics of an earlier sedimentary sequence or sequences. Such sedimentary sequences have been referred to the Warrawoona Series (Maitland, 1905; Noldart and Wyatt, 1962). In a number of areas the proportion of granite to sediment is approximately equal; the granite forms sheet-like concordant bodies and the association is typically migmatitic. Large basic intrusions are rare, but an abundance of dolerite or metadolerite dykes is noted. Quartz veins are frequent and a large serpentinite dyke trending east is seen in the south. Smaller patches of a similar rock are recorded elsewhere in association with the metasediments.

Probably in the majority of cases the metasedimentary relics are confined to the peripheral zone of the Archaean mass. The few structural measurements determined suggest that a major anticlinorium exists in this region. The structure has its long axis plunging 40° in a direction 130° and its core is occupied by granitic rocks. Higher grades of metamorphism probably have been developed in the southeast zone, but shearing forces have been active overall and have partially obliterated the evidence.

No detailed petrological work has yet been undertaken on this region, but the following summary notes give a brief outline of the main features.

A conglomerate from 20 miles west of Mt. Newman Homestead occurs interbedded with granite and mica schists. It carries pebbles of strained quartz and also quartz recrystallized into a mosaic of finely granular crystals showing sutured interfaces. Granulation of grain boundaries in the groundmass, which consists of quartz and small laths of muscovite, is evidence of shearing. Muscovite is occasionally found as trains of fine flakes cutting quartz grains, suggesting either a secondary origin for some of the mica or a mobilisation of this constituent during shearing.

Quartzites are not uncommon, generally consisting of a very fine grained quartz mosaic with a slight suggestion of banding, which may be emphasised either by a change in grain size or colour variations. Minute, irregularly shaped, opaque inclusions of an ore mineral are noted. Other accessories include muscovite, apatite, epidote and (?) rutile as rare geniculate twins.

Some of the quartzites show the early stages of mylonitisation. They show small lens-like areas of quartz cemented by a very fine grained groundmass of the same mineral. Relict ptygmatic folding has been identified.

Another example of quartzite, showing limited effects of shearing, consists of oval grains of quartz with sutured and granulated boundaries. The original, well-rounded shape of the grains is defined by a line of minute inclusions. Towards the centre, the quartz carried abundant trains of minute liquid inclusions many of which show included gas bubbles. Surrounding the original sedimentary quartz is more optically-continuous quartz carrying many small mica inclusions. The peripheral quartz and probably also the mica are thought to be diagenetic.

Jaspilites frequently occur towards the northern edge of the Archaean mass and though complexly folded show little or no sign of recrystallisation. However, one example, from near the southern limit of the Archaean area consists of coarse magnetite and quartz with pseudomorphs of limonite and quartz after a bladed mineral. No relics of the original mineral are preserved, but it is tentatively thought to have been an iron-rich amphibole, such as grunerite. The coarse-grained nature of the rock and its association in the field with mica schists and recrystallised quartzites indicate that regional metamorphism of a moderately high grade has been effective in this region.

Towards Deadman Hill basalts are the dominant Archaean rocks. They are dark-green, very fine grained and saussuritised.

Serpentine dykes occur in the south and southeast of the Archaean block and are probably a continuation of the suite seen in the Robertson map area. They are brown-weathering, dark-green rocks consisting of serpentine minerals with disseminated talc and cut by thin antigonite veins.

Granite, as large masses or sheet-like bodies, forms the majority of the Archaean block. The few examples examined consist of quartz, albite and slightly perthitic microcline with accessory green to green-brown biotite and rare muscovite. Both quartz and feldspar show the effects of slight shearing.

Pegmatites and quartz veins are not uncommon and are probably closely associated with the granites.

Basic dykes, forming striking patterns on the aerial photographs, are of frequent occurrence. Two main trends are recognised, (a) north-northeast and (b) northwest. Dykes trending east to west are recognised but are rare. No dykes were noted to cut the Mt. Bruce Supergroup in contrast to similar dykes in the Rocklea Dome which cut both the Archaean and Proterozoic rocks (de la Hunty, in press).

PROTEROZOIC

MT. BRUCE SUPERGROUP

The term Mt. Bruce Supergroup is given to include the Fortescue, Hamersley and Wyloo Groups of Proterozoic age. It is derived from the Mt. Bruce 1:250,000 Sheet where most of the members of the individual groups were first described.

FORTESCUE GROUP

These rocks are exposed along the northern edge of the area and largely conform to the descriptions given by MacLeod and others (1963).

The Hardey Sandstone occurs near the northern edge of the Turee Creek sheet area in the core of an anticline. Only one sandstone horizon is seen underlain by basalts. The lithology of medium to coarse grained, white, cream or brown weathering orthoquartzite is typical of this formation as developed in the type area in the Rocklea Dome.

In the core of the Wyloo Anticline, thin, coarse, white orthoquartzites, conglomerate, greywacke and rare thin calcareous bands occur at this horizon near the Belvedere Mine. A few miles to the east of this mine, Archaean acid gneisses have been reported.

In the Newman sheet area Hardey Sandstone has not been positively identified.

Pillow lavas of the Mt. Jope Basalt have been seen in several localities, but further work is needed to establish correlations with the pillow members of the type area.

On Turee Creek and Wyloo sheet areas, there is a general lack of sediments within the Jeerinah Formation. Sedimentary horizons are generally thin, consisting of lenticular cherts which weather pink, white and yellow and containing thin brown and olive sandstones and pebbly sandstones in the lower part of the section. The well developed cherts and shales which immediately underlie the Marra Mamba Iron Formation in the Yarraloola and Roy Hill sheet areas to the north are thinly developed on the Wyloo and absent from the Turee Creek sheet areas.

In the Newman sheet area wide areas of folded Jeerinah Formation are present, consisting of basalts and dolerites with interbedded shales, cherts, dolomitic shales, thin dolomites and impure sandstones. Copper mineralisation has been found at several localities in this formation and the Wonmunna deposits are typical (Low, 1963).

HAMERSLEY GROUP

The formations of the Hamersley Group form most of the high ground in the northern part of the area. A description of these rocks is given in MacLeod and others (1963). The stratigraphy of the area under discussion is the same as that already described, apart from an abnormal development in the Wyloo Anticline. Here the succession thins rapidly to the west and finally disappears. The thinning is thought to be a depositional rather than a tectonic feature, though strike faulting is common on the limbs of the fold in this area. Thinning occurs on both limbs of the fold and the outcrop can be completely traced on aerial photographs. Conglomerates, containing quartz, quartzite and jaspilite pebbles are also developed in the thinnest part of the section, as at Mt. Edith, and the Mt. McGrath Formation of the overlying Wyloo Group thins rapidly in the same direction. Conglomerates are a major feature of this formation.

As might be expected, the Brockman Iron Formation is the most persistent member of the Hamersley Group and can be seen in attenuated form as far west as Mt. Edith. The lithology of the iron formation is the same throughout, though there is a preponderance of thick cherty bands in the western part of the outcrop. Conglomerate horizons occur above and below the iron formation. Detailed mapping would probably show that they are lenses which die out rapidly along strike. The reason for the thinning is not clear; it may represent an old shore line or it may be due to uplift of the Wyloo Anticline during deposition of the sediments.

As in other areas to the north, concentric ripples (pseudofossils) are a moderately common feature of the Brockman Iron Formation. Two large examples were found on the north side of the Giles Point in the Newman sheet area (Plate 24, figure 1).

WYLOO GROUP

This group comprises a thick sequence of clastic sediments, basic volcanics and dolomitic limestones and conformably overlies the Hamersley Group. Unlike the Hamersley Group the sequence varies considerably along strike and is often tightly folded. Because of this and the monotonous nature of the rocks involved, the upper part of the sequence is not well known. The Wyloo Group outcrop includes most of the Ashburton Valley and the western margin of the Hamersley Range.

Turee Creek Formation

The outcrop of this formation extends from the nose of the Wyloo Anticline, where it is only 120 feet thick, to the core of the Turee Creek Syncline where a very large but unknown thickness occurs. In the westernmost areas the sequence is:—

Top—	Feet
Dark-brown and green-brown, maroon-weathering silty shales	about 60
Coarse grained, current-bedded sandstone and grit	25–30
Conglomerate	10–15
Maximum Thickness	105

These sediments overlie a thick sequence of saussuritised cleaved basalts which are present locally in the sequence.

Ten miles to the west of this locality the formation is much thicker and the lithology is more variable. In the area 10 miles east-northeast of Cheela Plains Outcamp the succession is very variable with rapid thickening and thinning of some members, including greywacke, dolomite, conglomerate, shale and quartzite.

To the north and south of this area it is known that a great thickness of orthoquartzite, greywacke, shale, dolomite and conglomerate is present within the formation. Unfortunately it is not well exposed and it is not possible to give a thickness. De la Hunty (in press) gives a thickness of about 1,000 feet near Meteorite Bore.

The Turee Creek Formation occupies a wide area in the core of the Turee Creek Syncline. It is poorly exposed but is estimated to be 1,500 feet thick. West of the Turee Creek Syncline the formation has a faulted boundary.

Beasley River Quartzite

This formation is widely distributed along the western and southern margin of the Hamersley Range and as far east as longitude 118°30′. The formation is variable, but consists essentially of white orthoquartzites, with some shale, sandstone and siltstone. Thickness varies along strike from only a few feet near Wyloo to about 600 feet in the core of the Turee Creek Syncline. It normally weathers to give strong steep ridges.

Lithologically, the quartzite is a medium to coarse-grained quartz sandstone which is often silicified and glassy. It is frequently banded and current bedding and ripple marks have been seen. Thin conglomerates, pebble strings, grits and thin shaly bands are occasionally observed. The rock normally weathers to give a white or cream, coarsely granular surface, though orange and mauve are not uncommon. Cracks and joints are frequently iron stained. Dolerite sills are well developed within the formation in the Turee Creek Syncline.

In the type area, near the nose of the Wyloo Anticline, some of the quartzites are dark-green and occur interbedded with thin, micaceous, silty shales. Also present is a thin conglomerate composed of small (1 in. to 2 in.) angular pieces of quartz and jaspilite set in a very coarse quartz sandstone matrix. The lowermost quartzite is maroon in colour and is brecciated due to movement during folding.

The formation thins rapidly to the west from the type area, finally ending on a fault contact at the western edge of the Wyloo Anticline. North of the Wyloo Anticline in the Urandy area, the quartzite is strongly developed and some repetition of beds by strike faulting is apparent. East of the type area, the formation is frequently thin or missing, again due to strike faulting, but the section is complete in the Turee Creek Syncline.

Mt. McGrath Formation

This formation was first mentioned by MacLeod and others (1963), who used the term Mt. McGrath Beds. This term is now obsolete. The formation comprises a series of shales, sandstones, greywackes, conglomerates, dolomites, quartzites and thin basalt horizons. A complete succession cannot be given, due to the faulted nature of the outcrops and the rapid lensing of the individual beds, along the strike, but de la Hunty (in press) gives the following succession from Meteorite Bore:

Top—Karlathundra Conglomerate Member	up to 1,300 feet
Coolbye Shale Member	about 100 feet
Cheela Springs Basalt Member	up to 5,000 feet
Nummana Member	about 120 feet

The *Nummana Member* is well exposed near the nose of the Wyloo Anticline, where the succession is:—

Top—Cheela Springs Basalt Member	
Nummana Member	
Shales and thin fine-grained quartzites	about 120 ft. thick
Flaggy bedded, micaceous siltstones	
Basalt, amygdaloidal at top	
Beasley River Quartzite	

This succession is similar to that seen in the Hardey Syncline, with the exception that thin volcanic bands are seen near the top of the section in that area. It can be traced with certainty only as far west as the Wyloo—Rocklea road, where it ends at a fault. East of the type area, its outcrop is uncertain but it probably occurs as far

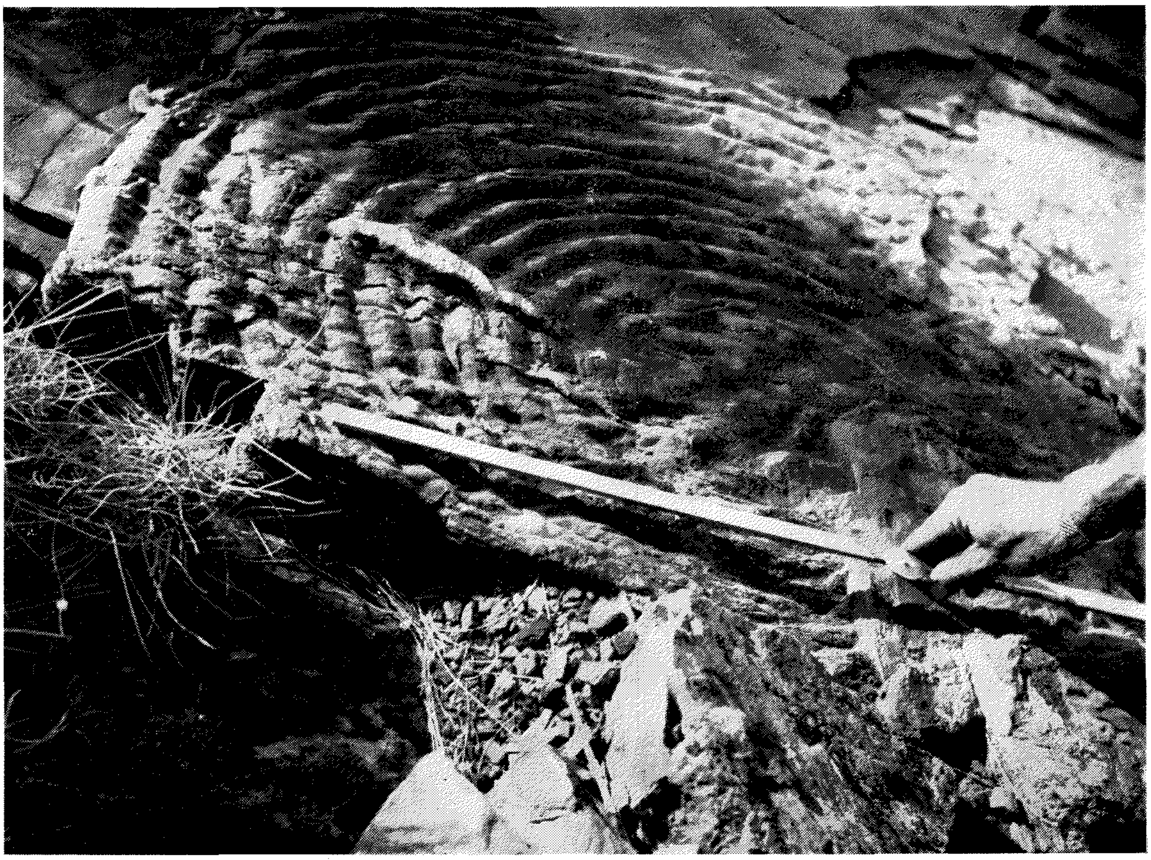

Figure 1. " Pseudofossil " in Brockman Iron Formation from west end of Giles Point, Ophthalmia Range, Newman sheet.

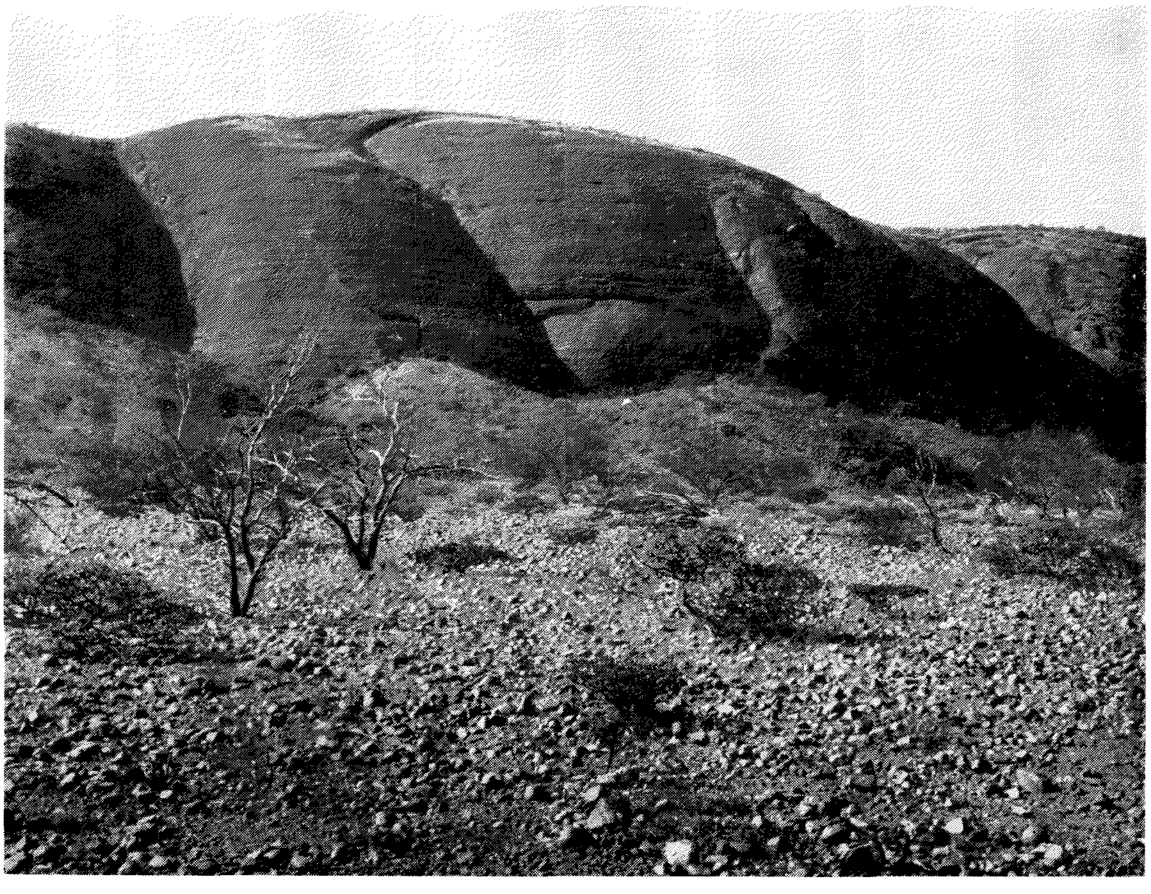

Figure 2. Mt. Bresnahan from the south, showing the Cherrybooka Conglomerate.

SKETCH SHOWING MINOR FOLD IN BROCKMAN IRON FORMATION

NEWMAN 1:250,000 SHEET

east as Mt. Channar. A section measured 8 miles northwest of Duck Creek Homestead consists of maroon-weathering shales with interbedded thin, brown sandstones and weathered dolerite or basalt.

The *Cheela Springs Basalt Member* was first named by MacLeod and others (1963). It occurs in two main outcrop areas on the north and south limbs of the Wyloo Anticline. It is at least 5,000 feet thick near Cheela Springs, though it thins and eventually disappears to the west and east. This thinning is partly due to faulting. In the southern outcrop, the basalts overlie the Nummana Member, while in the northern area the basalts immediately overlie the Beasley River Quartzite in some localities.

The member also occurs in the core of the Turee Creek Syncline and south of Neerambah ("Mud") Spring. The Nummana Member is probably not present at either of these localities.

The basalts are dark, fine-grained greenish, saussuritised quartz basalts. Some are amygdaloidal and several flows are recognised. Structures within the basalt are simple, with strong jointing and axial plane cleavage well developed in the nose of the Wyloo Anticline. Shearing is common and stretched and elongated amygdules are a feature in some areas.

The *Coolbye Shale Member* is a dark-grey shale which is conformable upon the Cheela Springs Basalt.

The *Karlathundra Conglomerate Member* comprises a thick pebble conglomerate, with a sandstone matrix, which thins rapidly to the west. It is conformable upon the Coolbye Shale.

The Nummana Member, Coolbye Shale and Karlathundra Conglomerate are not separable as mapping units in the area west of the Wyloo—Rocklea road where the Cheela Springs Basalt is missing.

Similarly they cannot be differentiated east or south of Meteorite Bore. For these areas the whole succession has been called the Mt. McGrath Formation, which thus comprises a series of shales, sandstones, greywackes, conglomerates, dolomite, quartzite and thin basalt horizons. A complete succession cannot be given due to the faulted nature of the outcrops and the rapid lensing of the individual beds along the strike. The name Mt. McGrath Formation supersedes the term Mt. McGrath Beds of MacLeod and others (1963).

A large thickness of these beds is exposed south of Mt. Channar, where the succession is largely arenaceous:—

Top—Shales, greywackes and thin conglomerates	Thickness about 3,000 feet
Banded siltstones and shales	
Sandstone and conglomerate	
Conglomerate with jaspilite fragments	
(Base not seen)	

Near Neerambah Spring, 10 miles along strike northwest of this locality, the beds exposed include thin dolomite beds, conglomerate, shales and basalts. A similar succession may be seen in a faulted block a further 35 miles to the northwest and within 10 miles of Meteorite Bore.

Between Mt. Edith and the Wyloo—Rocklea road, the formation is much faulted and shows a rapidly changing sequence of conglomerate, shale, grit, dolomite, greywacke, sandstone and quartzite which thins to the west. The conglomerate includes jaspilite fragments in some places.

From this description it can be seen that the Mt. McGrath Formation is a very variable one which is thicker and more arenaceous to the southwest and shows shallow-water rocks throughout its strike length. The presence of jaspilite fragments in several conglomerates suggests that the Hamersley Group formed at least one source of supply for these rocks. In all cases the Mt. McGrath Formation is overlain conformably by the Duck Creek Dolomite.

Duck Creek Dolomite

This formation was first named by MacLeod and others (1963). It is the most persistent unit of the Wyloo Group and extends from Mt. Edith in the west of the Angelo River region in the southeast and beyond Deepdale to the north of the area shown in Plate 26. It is characterised by the presence of stromatoliths, and these permit its identification even in isolated outcrops. There are several lithological types present, but the general impression in the field is of a thick bedded yellow or orange-weathering dolomite with some chert bands. The following section was measured at Duck Creek Gorge, in the type area for the formation, by H. S. Edgell, J. L. Daniels and R. Halligan in 1963:

(Uppermost contact unexposed)

	Feet
Top—Mauve-weathered, grey, thin bedded dolomite with mesh type silification and stylolites	145
Fault and 15 feet of steep-dipping, brown-weathered, greyish dolomite together with a thin intrusion of basalt and agglomerate with pyrites	15
Well-bedded dolomite becoming more thin-bedded upwards. Colour fawn to yellow-grey without obvious algae	1,070
Thick-bedded to massive, dark, orange-weathered, siliceous dolomite with large diameter columnar *Collenia*	670
Thick-bedded, orange - weathered dolomite with interbedded *C. undosa* and small columnar *Collenia*	700
Massive, orange-weathered dolomite with abundant *C. undosa*	?160
Dark, silicified dolomite with abundant wavy, siliceous laminae	550
Minimum Thickness	3,300

The Duck Creek Dolomite is overlain conformably by the Ashburton Formation. Both upper and lower contacts are sharp, showing little or no gradation with the adjacent clastic beds. In many cases, however, the contacts are faulted and in such cases the algal fossils have proved to be good markers.

Ashburton Formation

This formation was first named by de la Hunty (in press) and replaces the term "Greywacke" as used by MacLeod and others (1963). Earlier workers (Maitland, 1909; Talbot, 1926) included the formation in the Ashburton Beds together with the other members of the Wyloo Group. At that time they regarded these beds as equivalent to the Mosquito Creek Series of Archaean age. The latest work has shown that these beds are among the youngest in the area. The formation extends from the Robe River in the north, throughout the Ashburton Valley and as far east as Tunnel Creek in the Newman sheet area where it disappears beneath the overlying Bresnahan and Bangemall Groups.

The Ashburton Formation comprises a great thickness of shales, sandstones, conglomerates and greywackes, with minor amounts of dolomite, calcareous shale, quartzite and both acid and basic igneous rocks. In the region of June Hill and Mt. Stuart, volcanic agglomerates, tuffs, acid volcanics and jaspilite are well developed, but such rock types are rare within the formation. Due to changing lithology along strike and complicated folding, no estimate of the thickness of the formation is given.

In the field the formation has a monotonous aspect and generally occupies the low ground, but occasional high ridges and erosion remnant peaks do occur. The Capricorn Range south of Ashburton Downs homestead forms such an example. Cleavage and minor folding are well developed and in a few areas (e.g. Top Camp) phyllites, schists and some gneisses are developed in the cores of folds.

In the area between Mt. Amy and Duck Creek, on the Wyloo sheet, a great thickness of shaly sandstone and greywacke is developed, together with thinner, interbedded shale and conglomerate horizons. The greywacke-sandstone units contain a noticeable proportion of red jasper grains, which are most probably derived from the Hamersley Group. The conglomerates are occasionally quite striking rocks in outcrop, with boulders and pebbles of dolomite and thin short lenses of dolomite interbedded in the normal coarse sandstone and quartz conglomerate lithology. All the rocks in the area have a well developed west-northwest to northwest cleavage.

In the June Hill area, an unusual development of the formation is seen. A thick (300 feet) coarse, angular, volcanic agglomerate with associated waterlain tuff bands, extends over a strike length of 8 miles and a width of up to three quarters of a mile. It is overlain, with local unconformity, by a thin development of conglomerate, shale, dolomite and jaspilite. The whole sequence is folded with the normal regional trend and appears to be restricted to this area. Jaspilites seen on Mt. Stuart, 14 miles west of this area, may be the equivalents of the jaspilites of the Mt. June area. The agglomerates and tuffs are quite spectacular rocks in the field. The basal conglomerate of the overlying sediments is also very unusual, in places consisting of large boulders of dolomite and jaspilite enclosed in a dolomite matrix. Occasional erratic pebbles are seen but most of the fragments could have been derived locally. It is thought that the rocks represent a local, violent volcanic episode within the Ashburton Formation. Petrological examination of the agglomerate and associated lava beds shows that they have affinities with the Woongarra Dacite acid volcanics of the Hamersley Group.

The succession at Mt. Stuart includes greywackes, shale and broadly banded jaspilites, which have been folded into very sharp, steep folds. Examination of the minor structures indicates that two periods of folding were involved. Thin jaspilites are also seen at a similar stratigraphic horizon about 10 miles to the north of Mt. Stuart.

Mapping is not yet completed in the Ashburton Formation, but the evidence so far suggests a rather variable succession.

In the Kennedy Creek area, east of the Turee Creek sheet area, an attempt was made to establish a sequence.

		Feet
	(Top of section not present)	
Ashburton Formation	Maroon and pale-green shales with rare grits, showing current bedding towards base	10,000
	Dominant dark-brownish grits with few shale bands	9,900
	Cleaved maroon shales with some grits	4,900
Duck Creek	Dolomite greater than	1,100
	(No base exposed)	

In the upper part of the section no folding was noted, but along strike to the northwest tight folding is present. One exposure in the top section shows bedding and cleavage to be parallel, indicating that isoclinal folding may be present. The thicknesses given are possibly suspect. A thickness of 75,000 to 80,000 feet was postulated for the Ashburton Beds by Talbot (1926) but he considered that this apparent thickness was due to isoclinal folding, even though he saw no fold crests. A similar thickness could be postulated for the Ashburton Formation northwest of the Wyloo Anticline. Here, however, there are several indications of tight folding. The present conclusion is that the thickness might not be great and that the apparent thickness is due to repetition by tight folding in a flat bottomed fold. Similar examples of such folding have been seen in the Boolgeeda Iron Formation towards the western end of the Brockman Syncline.

BRESNAHAN GROUP

A thick series of arenaceous beds occupies an area of some 1,080 square miles in the region bounded by Turee Creek homestead, Prairie Downs homestead, Tunnel Creek, Mt. Bresnahan and Oregons Pool. These beds unconformably overlie the Wyloo Group in the west and are unconformably overlain by the Bangemall Group in the south and southeast. They are faulted against the Mt. Bruce Supergroup in the north and the Archaean in the east. The name is given after Mt. Bresnahan, a dominant landmark on the Turee Creek Sheet.

A division into two formations is possible:—

		Feet
Bresnahan Group	Kunderong Sandstone	1,000–40,000
	Cherrybooka Conglomerate	20– 400

Cherrybooka Conglomerate

The name is derived from a tributary of the Angelo River, the Cherrybooka, which drains the area immediately to the north of Mt. Bresnahan.

A thickness of approximately 400 feet of conglomerate and coarse pebbly sandstones is present at Mt. Bresnahan (see Plate 24, figure 2), but immediately to the north of the Kennedy Creek it measures only 30 feet. A similar thickness is probably present at the base of the group forming the isolated outlier of Boggola, and a possible maximum of 20 feet was noted along the track from Mt. Vernon to Turee Creek homestead at a point 20 miles south-southwest of Turee Creek homestead. Further east, the base of the formation is not exposed.

The vast majority of the boulders and pebbles making up the deposit consist of fine-grained, sedimentary quartzite, white, grey and mauve in colour and sometimes showing cross bedding. Conglomerate boulders are not infrequent and usually the constituent pebbles of glassy quartz show iron stain surfaces. More rarely, boulders of white vein quartz carrying small amounts of white mica, are found. Some boulders of contorted black jaspilite resembling rocks from the Archaean of the Newman sheet area, and some pebbles of amphibolite were seen. The matrix of the conglomerate is a medium-grained, mauve grit with variable mica content. In some bands it dominates over the boulders, when it then shows crude cross bedding.

Both the sedimentary quartzite and the conglomerate boulders bear a strong superficial resemblance to samples from the Beasley River Quartzite. The remaining boulders could have been derived from an Archaean mass. It is tentatively concluded that the Cherrybooka Conglomerate was deposited in an uneven basin, with the majority of the material being derived from the north. The absence of boulders of the formations other than the Beasley River Quartzite could be explained by prolonged weathering of the deposit whereby only the most stable materials would remain.

Weathering of the Cherrybooka Conglomerate, especially at Mt. Bresnahan, produces flanking screes of boulders and gently sloping fans with a superficial covering of boulders. Recementation of the boulder screes has taken place and produces a rock almost identical to the original conglomerate.

Kunderong Sandstone

The upper formation of the Bresnahan Group forms characteristic low, rounded, isolated hills covered with large, loose flagstones. It is well exposed in the Kunderong Hills near Turee Creek Homestead.

The formation consists of a thick sequence of brown-weathering, white to fawn grits and sandstones. Occasional pebble beds occur but are thought to be lenticular and of short lateral extent. Current bedding is a common feature but ripple marks are rare. No systematic vertical variation was detected and the slight changes noted appeared to be local. Such variations consist of colour difference, amounts of mica, degree of secondary silicification and thicknesses of the component layers.

In thin section a typical sample consists of quartz and feldspar with traces of mica, glauconite and accessory tourmaline, zircon, apatite, iron oxides and rare anatase. The proportion of feldspar ranges from approximately 5 per cent. to 50 per cent. and consists dominantly of fresh microline or microcline-microperthite and smaller quantities of albite or albite-oligoclase.

The majority of the sandstones show the effects of secondary silicification. The well rounded outlines of the original quartz grains are frequently preserved and diagenetic quartz has been deposited in optical continuity around these cores. A shadowy extinction pattern crosses both the original and secondary quartz confirming that deformation, possibly during folding, took place after the silicification. The latter is not, therefore, a recent surface phenomenon.

Little work has yet been undertaken on the heavy-mineral assemblages, which are of limited variation. Well rounded tourmaline of various colours is dominant. Zoned zircon is usually subsidiary to the tourmaline but occasionally dominates. In both cases secondary overgrowths have been noted. Other heavy-minerals identified include apatite, iron ore, muscovite and anatase.

Both the light and heavy fractions confirm that the source material was largely of granitic composition, and might have been derived from the Newman Archaean mass.

The isolated nature of the exposures of Kunderong Sandstone precludes any direct measurement of the total thickness. Much lateral variation in thickness is apparent for the underlying conglomerate and though no similar feature has been seen in the sandstones, the same probably applies. Towards the southeastern limit of the Kunderong Sandstone exposures, an apparently unbroken sequence over a distance of approximately 8 miles dips at 53°. A minimum thickness can be estimated, therefore, at some 40,000 feet. No repetition through strike faulting was noted, isoclinal folding was not detected and all the minor folds, which were not abundant or strong, plunged in a direction of 70°. Such a thickness is unusual for this lithology and might be due to sedimentation in a local basin which was controlled by the Prairie Downs Fault. Another possible explanation is that offlap or overlap might be present causing an abnormally wide outcrop for a relatively thin sequence.

Sheets of quartz dolerite intrude the Kunderong Sandstone in the region of Prairie Downs and Turee Creek homesteads. They are dark, fresh, medium-grained rocks composed of plagioclase and augite in ophitic relationship. Accessories include brown-green hornblende rimming the pyroxene, red biotite, chlorite, iron ore, green epidote and apatite, which is usually confined to interstitial areas of granophyric intergrowth of quartz and feldspar.

The plagioclase is commonly strongly zoned with cores of calcic labradorite grading to peripheries of calcic oligoclase, the latter then often forming an interstitial granophyric intergrowth with quartz.

An increase in grain size from bottom to top is the most noticeable change in samples from the sills immediately west of Prairie Downs homestead and in the upper parts, the pyroxene tends to form quarter inch to half inch phenocrysts. Other less obvious changes, from bottom to top, include an apparent increase in the granophyric intergrowth content and a change from skeletal iron ore to a subhedral variety. In the middle and upper sections of one sill the augite showed frequent simple twins. This feature was not developed in the augite at the base.

BANGEMALL GROUP

The Bangemall Group is exposed over a wide area in the southern part of the Turee Creek and Newman Sheet areas and is known to extend well to the south and east of these areas into the Edmund, Egerton and Collier sheet areas. It is also believed to form the Parry Range in the southwest of the Wyloo Sheet. Rocks from this group were first recorded by A. Gibb Maitland (1909) who described the succession in the neighbourhood of Bangemall, Wandarry ("Secret") Creek and Mt. Phillips. Maitland used the name "Bangemall Series" for these beds.

A section, traversed through the group from north to south, was made in the Fords Creek—Godfrey Range area as follows:—

Top—

Kurabuka Formation	Buff, greenish and grey shales, silty shales and thin quartzite. White, medium grained orthoquartzite.
Fords Creek Shale	Buff shales with thin, dark-coloured, interbedded quartzite bands. Quartzites more abundant towards top of sequence. Dolerite sill. Greenish-brown shales Dolerite sill. Greenish shales and silty shales. Dolerite sill. Greenish-brown, dolomitic shales and silty flags.
Top Camp Dolomite	Flaggy-bedded dolomite, with occasional dark, blue-grey dolomite beds. Pale-grey dolomitic shales. Dolomites with chert bands. Medium-bedded, brown and pale-grey-weathering dolomites with occasional breccia beds. Thick-bedded, fawn-weathering dolomites. Chert and cherty shales. Quartzite and sandstone with slump structures. Dark-grey, banded shales with interbedded sandstone bands. Thick-bedded dolomite. ——— Disconformity ——— Black shales. Dolerite sill. Thin, grey shale and quartzite. Thick-bedded, buff dolomite, with some buff quartzite horizons. Occasional chert bands. Stromatolithic near base. Shales, fine conglomerate and sandy dolomite beds, sometimes glauconitic.

——— Unconformity ———

Base. Ashburton Formation.

The unconformity at the base of the sequence is well marked. Rocks of the Bangemall Group dipping at 5° to 10° to the south overlie tightly folded, cleaved phyllitic shales and silty shales of the Ashburton Formation. Dips on the latter are of the order of 60° and the fold axes plunge at 40° to 140°. This unconformity, known as the Top Camp Unconformity was mentioned and figured by Maitland (1919) and later described and figured by Talbot (1926). In the southeast corner of the Turee Creek sheet area and on the west part of Newman Sheet area the Bangemall Group unconformably overlies the Bresnahan Group. Further east and southeast they directly overlie the Archaean.

Top Camp Dolomite

The basal beds of the Bangemall Group vary from place to place. Near Top Camp the lowest beds include a few thin, gritty bands and green shales. Further to the east in Irregully Creek, Maitland (1909) recorded a 2 or 3 foot conglomerate horizon, while west of Top Camp, near Pingandy Creek, a few inches of conglomerate is followed by some gritty bands in the overlying sediments. Near Prairie Downs at least 1,000 feet of conglomerate occurs. This development seems to be local and is probably due to control of sedimentation by the Prairie Downs fault. The evidence available does not correlate these basal conglomerates. It seems that the conglomerate at Prairie Downs is younger than those to the west and was laid down on a floor of Bresnahan rocks upon which lay isolated erosional relics of Top Camp Dolomite. At what stage in the deposition of the Bangemall rocks this took place is not known, but several points of evidence suggest that the basin of deposition near Prairie Downs was unstable on several occasions. The evidence is summarised below:—

(1) The presence of intraformational breccia in the Top Camp Dolomite.

(2) An erosional relic of Top Camp Dolomite 16 miles south of Prairie Downs.

(3) The presence of orthoquartzites at several horizons in arkosic and conglomeratic sediments south of Prairie Downs. The orthoquartzites probably indicate periods of stability while the arkoses probably represent periods of rapid sinking.

Stromatoliths occur in the lower part of the Top Camp Dolomite. Several types were seen in a thin succession about 40 feet above the base at Fords Creek. They occur in a regular sequence, the lowest being *Collenia undosa* type and the highest a *Conophyton* type. *Collenia undosa* also occurs higher in the succession at two other horizons below the first dolerite sill. Further work is to be done on these fossils by H. S. Edgell.

The dolomites of the formation are of several types. The most common is a thick-bedded, buff-weathering, tough, pale-grey, crystalline dolomite, which forms bold cliffs and escarpments. Near the top of the section, brown and white or grey dolomites occur. These are generally medium to thin-bedded carrying a few 1 to 4 feet thick beds of limestone breccia. Some of the beds show irregularly intergrown limestone and dolomite patches. The highest beds are flaggy-bedded and shaly, with chert bands and cherty patches becoming a feature.

Interbedded with the dolomites are several thin quartzite and shale horizons. The quartzites are buff, brown or white, medium to coarse-grained orthoquartzites. One such horizon shows slump structures in the top eight feet of a twelve-foot bed. A minor unconformity occurs within the dolomite below this horizon. The shale horizons include dark-coloured shales, cherty shales and a thick, black, brittle shale which displays a white or yellow efflorescence of chemical salts in some exposures, particularly near the junction with the underlying sill.

Fords Creek Shale

This comprises a thick sequence of greenish-brown coloured shales and silty shales, dolomitic near the base with thin interbedded mudstones, dark, fine-grained quartzites and rare coarse-grained orthoquartzites. Thin dolerite sill are a feature of this formation. Quartzite beds become more common towards the top of the sequence.

Kurabuka Formation

This comprises white, medium-grained orthoquartzites with white and greenish shales and silty shales, together with interlayered dolerite sills. The basal quartzite of the formation forms a steep, well marked escarpment and is a good mapping horizon. The shales are similar in type to those of the underlying Fords Creek Shale. Wells in these beds invariably give brackish water and some of the streams draining them are salty.

In the west the Bangemall Group has been folded on northwest trending axes. Faulting is not great. Dolerite sills are a feature of all the formation within the Group and saline shales are common to all three divisions.

Shales, sandstones and dolerites of the Bangemall Group are poorly exposed in the southeast of the Newman Sheet in the area between Weelaranna and Bulloo Downs. The rocks dip at very shallow angles and do not form prominent hills. The dolerites are thought to be transgressive. No basal dolomite is found in this locality though a thin, manganese-stained dolomite overlying bright-green and maroon shales is found higher up in the sequence. Its relation to the normal succession to the west is not known.

STRUCTURE

The broad structural features of the Hamersley Iron Province have already been adequately described by MacLeod and others (1963) and only a brief summary is necessary. They divide the area into three main easterly trending zones:

(1) Northern zone.

(2) Central zone.

(3) Southern zone.

Each zone is characterised by certain features concerning the folding. The division, however, is one of convenience rather than accuracy, since the units are strictly parts of a single, regional tectonic pattern.

A simplified description of the folding affecting the Mt. Bruce Supergroup, and based on all the evidence now available, states two main features. Firstly that the intensity of folding increases to the south and southwest and secondly that two fold systems have acted over large areas. The interference of these systems is responsible for the large-scale dome and basin structures.

Additional information was gathered on some of the minor structures during the present study and fully support the previously deduced tectonic pattern. The following are a few remarks on the effects of folding on some of the rock types of the Mt. Bruce Supergroup.

"Ripple marks" are an almost ubiquitous feature of the Brockman Iron Formation and some of these were examined in detail. On the northern limb of the Wyloo Anticline, Brockman Iron Formation is exposed as steeply dipping beds. The bedding dips at 62° in a direction of 221°. "Ripples" are well developed on these surfaces. The crest of the ripples plunges at angles ranging from 9° to 15° while the plunge direction ranges between 120° and 143°. Minor folds in the jaspilite are horizontal with an axial strike of 140°. A similar direction is to be seen in the shear planes cutting the basalts immediately to the south. The main axis of the Wyloo Anticline trends approximately 120° as determined from aerial photographs. There appears to be a fairly close correlation between the trend of the ripples, the main fold axis trend and the minor structure associated with the fold.

Immediately northeast of the Turee Creek Syncline, Brockman Iron Formation forms an anticline and in this area shows little or no evidence of having been subjected to the effects of crossing fold systems. From uncontrolled aerial photographs the axial trend in this region is 292° to 295°, with a very low plunge to the northwest. In this area, measurements were made on the minor folds and the "pinch and swell" structures which appear as ripples on bedding planes. Measurements of axes of minor folds in the axial region show a spread from 290° to 295° with a plunge of 5° to 11° to the northwest. Hence the minor folds are shown to be parallel to the main fold axis. Outside the main axial region a greater spread is apparent and the whole group shows a concentration around 280° with a plunge of 10° to 15° to the northwest.

"Pinch and swell" structures are confined to the limbs of the fold. They are not present in the axial region where the beds are tightly folded. Measurements were made on the long axis of the pinch and swell structures (i.e. parallel to the "ripple" direction), and the arithmetical mean for these gives a plunge of 7° and a plunge-direction of 281°. This agrees very closely with the mean for the whole group of minor folds.

It is concluded that the ripples, seen as pinch and swell structures in section in this anticline, have been produced by the folding and are considered to be akin to boudinage structures.

Immediately north of Wyloo homestead, drag folds in the Brockman Iron Formation produce features which in cross section resemble "pinch and swell" structures.

A minor fold from the Brockman Iron Formation in the northwest corner of the Newman 4-mile sheet area illustrates, in one specimen, both these features described above (i.e., boudinage and drag folds) and illustrates their relative relationship. A diagram of the specimen is given in Plate 25. "Pinch and swell", or boudinage structures can be seen towards the outer parts of the fold, while drag folds resembling "pinch and swell" occur towards the centre and more intensely folded region. An axial plane cleavage is also developed.

Elsewhere, the most pronounced effects of folding are seen in the basalts and dolerites of the Mt. Jope Basalt, and in the various lithologies of the Ashburton Formation. The pattern of folding in the Jeerinah Formation, as seen on aerial photographs, closely resembles that of the minor folds seen in jaspilites of the Hamersley Group. In hand specimen, however, the effects are not so spectacular and are mainly confined to the production


GEOLOGICAL SURVEY OF WESTERN AUSTRALIA
GEOLOGICAL MAP
OF THE
ASHBURTON VALLEY REGION
SCALE OF MILES
10 5 0 10 20
Geology by J.L Daniels, R Halligan, W.R Jones
W.N MacLeod
REFERENCE
Superficial deposits
Robe Pisolite
BANGEMALL GROUP
Kurabuka Formation
Fords Creek Shale
Top Camp Dolomite
Undifferentiated
BRESNAHAN GROUP
Bresnahan Group
WYLOO GROUP
Ashburton Formation
Duck Creek Dolomite
McGrath Formation with Cheela Springs Basalt
Beasley River Quartzite
Turee Creek Formation
HAMERSLEY GROUP
FORTESCUE GROUP
Archaean granite basalt metasediments.
SYMBOLS
Geological boundary
Fault
Synclinal axis
Anticlinal axis
Watercourse
Road
Homestead
Prominent hill
LOCATION MAP
BROOME
PORT HEDLAND
ONSLOW
ROEBOURNE
CARNARVON
MEEKATHARRA
GERALDTON
PERTH
STRUCTURAL DIAGRAM
30 20 10 0 30
SCALE OF MILES
Duck Creek Syncline ①
Boolgeeda Syncline ②
Wyloo Anticline ③
Ashburton Fold ④
Bangemall Syncline ⑤
Turner Syncline ⑥
Jeerinah Anticline ⑦
Yandicoogina Syncline ⑧
Weeli Wolli Anticline ⑨
Mt Robinson Syncline ⑩
Wonmunna Anticline ⑪
Turee Creek Syncline ⑫
Mt Newman Syncline ⑬
Kalgan Creek Syncline ⑭
Shovellana Syncline ⑮
Cane River
Mt Amy
Urandy
Mt Farquar
Hamersley
WITTENOOM GORGE
FORTESCUE RIVER
Mt Stuart
Nanutarra
Boolaloo
Boolgeeda Camp
Duck Ck
Mt Bruce
Juna Downs
Marillana
ROY HILL
Mt Alexander
Wyloo
Meilga
Mt Wall
Mt Turner
Rocklea
Kooline
Glen Florrie
Cheela Plains
Ullawarra
Ashburton Downs
Seven Mile Ck
Mt Newman
Sylvania
Mininer
Turee Ck
Prairie Downs
Edmund
Boggola
Mt Bresnahan
Deadman Hill
Elliot Creek (Wanna)
Bulloo Downs
MUNDIWINDI
INDEX TO 1:250,000 MAP SHEETS
YARRALOOLA
WYLOO
MT BRUCE
ROY HILL
BALFOUR DOWNS
EDMUND
TUREE CREEK
NEWMAN
ROBERTSON
115° 30'
117° 0'
118° 30'
120°
121° 30'
21°
22°
23°
24°
22° 15'
23° 0'
24° 0'
116° 0'
117° 0'
118° 30'
120°
June Hill
Belvedere
Mt Edith
Mt McGrath
Metawandy Ck
Duck Ck
Silent Sisters
Koolina
HARDEY RIVER
Cheela Plains
Meteorite Bore
Rocklea
BEASLEY R.
ASHBURTON RIVER
Irregully Ck
Ashburton Downs
CAPRICORN RA.
Seven Mile Ck
Neerambah
'Mud' Spring
Turee Creek
Nanutarry Creek
Top Camp
Fords Ck
Boggola
Mininer
Angelo River
Kenneth Ck
Mt Bresnahan
Ingandy Creek
Oregons Pool
Turee Ck
KUNDERONG RA.
Tunnel Creek
Prairie Downs
Deadman Hill
Perry Creek
Weeli Wolli Ck
OPHTHALMIA RANGE
Mt Newman
Giles Point
FORTESCUE R.

of axial plane cleavages and shear belts. The latter are accompanied by mineralogical changes leading to the production of actinolite schists and ultimately chlorite schists with or without talc. Many good examples of this transformation can be seen in the Mt. Jope Basalts in the core of the Wyloo Anticline.

Throughout a large part of the Ashburton Formation, and especially in the more argillaceous sections, bedding is difficult to identify because of the strong development of cleavage and rods, which are the dominant structural features.

A close examination of the shales in places reveals bedding, which dips generally between 10° and 45°. Very high dips are uncommon. Measurements of bedding planes were plotted on a Schmidt net for both Ashburton Formation and Mt. Bruce Supergroup rocks and both show a similar elongated girdle. This suggests that the overall structure of the Ashburton Formation is similar to that of the Mt. Bruce Supergroup rocks to the north.

Exposures near Kennedy Creek show that the main folding which affected the Mt. Bruce Supergroup had finished before the Bresnahan Group was laid down. It is almost certain that the cross folding, affecting the Mt. Bruce Supergroup, had also finished since this trend is not found in any of the younger rocks. The Bresnahan Group was also folded before the deposition of the Bangemall Group, which has itself been folded. Thus, four fold-periods have been recognised as having affected the Proterozoic of this region (see Table 2).

TABLE 2.—FOLD PERIODS AFFECTING THE PROTEROZOIC ROCKS OF THE ASHBURTON VALLEY

Name of Fold Period	Main Trend	Youngest Rocks Affected
Edmundian	NW in western part .... E in eastern part	Bangemall Group
Newmanian	Approximately E	Bresnahan Group
Rocklean	Approximately NNE	Mt. Bruce Supergroup
Ophthalmian	NW in western part .... E in eastern part	

Faulting is common throughout the area, but there is a marked northwest trending belt of strong dislocation bounding the western end of the Hamersley Range. This belt extends from Deepdale, north of the area under discussion, through Urandy and Duck Creek stations to Meteorite Bore and beyond. Most of the faulting is normal strike faulting, but there has also been some transcurrent movement in the Duck Creek region. Repetition of beds is a common feature throughout the belt, over a width of up to 8 miles in places.

The north and south limbs of the Wyloo Anticline show extensive strike faulting, and, in part, this has contributed to the westward thinning of the outcrop of the Hamersley Group. In a similar way, the narrow sliver of the Hamersley and Wyloo Groups, northeast of Ashburton Downs, has been affected by faulting, with the result that the Woongarra Dacite, Boolgeeda Iron Formation and Beasley River Quartzite are rarely seen in this region.

It is interesting to note that this zone of faulting lies along one of the normal joint directions associated with east-west folding, as developed over much of the region. However, faulting along the complementary northeast trending joint direction is not common, except near Mt. Newman. No explanation can be given at this stage, but it is possible that the basement underlying the central Hamersley region was stable, and that a zone of tectonism existed within the basement beneath the intensely faulted zone. This would explain the areal restriction of the intensely faulted zone, and also the paucity of faulting and the gentle nature of the folding over most of the Hamersley Range.

SUPERFICIAL DEPOSITS

At several localities within the Ashburton Valley, thick deposits of calcrete, calcareous shale, ferruginised sands, grit and occasional pisolitic limonite occur, e.g., Table Top Hill near Ashburton Downs homestead and southwest of Turee Creek. These rocks are remnants of a previously existing and more extensive body which largely covered the upper part of the Ashburton Valley. They are thought to be equivalent to the Oakover Formation of the Fortescue Valley (de la Hunty, in press) and possibly also the colluvium and Robe Pisolite of the Robe River drainage system.

An area of some 300 square miles southwest of Turee Creek homestead is covered by windblown sand. Smaller deposits are known from 14 miles east-northeast of Ashburton Downs and 6 miles west of Boolaloo. These deposits generally support spinifex and Grevillea vegetation, and chain dunes are a common feature.

ECONOMIC GEOLOGY

Large hematite deposits have been found in the Brockman Iron Formation at several localities in the Newman and Roy Hill sheet areas. A large concentration of ore zones has been located around Weeli Wolli where MacLeod (1964) estimates the presence of 40,000,000 tons of ore per foot of depth. It is estimated that the depth ranges between 50 and 200 feet. A large single deposit, also in the Brockman Iron Formation, occurs in the northwest corner of the Newman sheet area and minor deposits also occur in the Marra Mamba Iron Formation of this area. At the 7-mile Creek gorge, northwest of Ashburton Downs, at least 100,000,000 tons of high grade hematite ore is known to occur in one major body and several small ore bodies have been found in the Brockman Iron Formation of the same area. Limonite deposits are rare and confined to thin residuals along a few river channels.

Sporadic copper mineralisation is known to occur in the Jeerinah and Ashburton Formations. In the former, the source material may have been pyrite nodules in nearby dolomitic shales. In the latter, the source is not known, but the majority of the occurrances are confined to short veins trending parallel to local anticlinal axes. A description of the majority of these deposits is given by Low (1963).

Galena, with siderite, pyromorphite and quartz, has been worked at the Silent Sisters Mine near Wyloo, where it occurs in northeast trending veins in Duck Creek Dolomite. Other lead occurrances are well known from the same region, and also from Kooline, Uaroo and Ashburton Downs.

Small amounts of galena with cerussite and barytes have been found in the Prairie Downs fault zone some 14 miles southeast of Prairie Downs, and this area could well repay further investigation.

Gold was recovered in the Ashburton Valley at several localities. Most of the gold was alluvial and came from such workings as Soldiers Secret on Wandarry Creek and Top Camp. Reef gold was mined at Dead Finish, near Ashburton Downs and the Belvedere Mines. The best account of these workings is given by Simpson *in* Talbot (1926).

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NOTES ON THE NOMENCLATURE AND SIGNIFICANCE OF "PORPHYRY" AND "PORPHYRITE" IN WESTERN AUSTRALIA

By A. F. Trendall

ABSTRACT

The terms "porphyry" and "porphyrite" carry many different meanings in geological literature. It is recommended that "porphyrite" be dropped but "porphyry" be retained, essentially as a field term with a wide petrographic coverage. Porphyries are abundant in the Precambrian of Western Australia; some of their petrographic features present problems which are not yet solved, and they may be closely related genetically to sedimentation.

INTRODUCTION

In 1962-63, in considering whether the Geological Survey should adopt a particular standard nomenclature for igneous rocks, and if so which, the status of the commonly used name "porphyry" was examined, as exemplifying many of the familiar difficulties of rock nomenclature. The results of that examination are summarised below, together with a brief progress report on current studies of porphyries from various Precambrian areas of Western Australia.

DEVELOPMENT AND USAGE OF THE TERMS "PORPHYRY" AND "PORPHYRITE"

General

Johannsen (1937, p. 81-84) has given a full review of early usage which is summarised in the remainder of this paragraph. The earliest Latin form is "porphyrites", and the ultimate derivation is from the Greek πορφυρχ (= purple) after the rock from a single dyke at Djebel-Dokhan, in Egypt, which was much used in ancient building and statuary. "Porphyr", "porphyry", "porphyrites", "porfido" and "porphyre" were used with indiscriminate synonymy in the various European languages through the 18th century for many rocks having the spotted appearance of the original. The early 19th century petrographers used "porphyry" or "porphyr" mainly to denote any rock with feldspar phenocrysts in an aphanitic matrix, and other forms had fallen into disuse. Variously defined usages of both "Porphyr" and "Porphyrit" were suggested by the classical German petrographers during the late 19th century, but the final authority for this school can be taken as Rosenbusch's last (1907-8) edition of his Physiographie (as interpreted by Johannsen, 1939, p. 124). There, "porphyry" is an older quartz-free extrusive rock with potash-feldspar and some plagioclase, whereas "porphyrite" has acid plagioclase. They are chemically equivalent to the "younger" trachyte and andesite respectively. However, before the usage of the terms had become systematised, the United States Geological Survey, in unpublished circulars of 1897 and 1898, had banned both of them, on the grounds that "porphyry" was only a textural term and could properly be used only in combination with a rock name, as in "granite-porphyry", and so forth.

Johannsen (1937, p. 84) summarised his own review thus: "porphyry and porphyrite represent, respectively, the porphyritic equivalents of the granites and the plagioclase-bearing rocks. *In this sense the terms are used everywhere except in the United States*" (my italics). And further on: "Personally I prefer to retain both porphyry and porphyrite, using them respectively for the orthoclase and the plagioclase aschistites of porphyritic habit." Johannsen does not use either term as a heading, but he discusses them under 2210 and 2212, thus clarifying his view of them as hypabyssal porphyritic equivalents of trachyte and andesite, which, for porphyry, is far from the porphyritic equivalent of granite.

In the light of this discrepancy Johannsen's italicized statement above would make his own (and Rosenbusch's) usage a departure from the general one. But is this statement true? Among British text-books Hatch, Wells and Wells (1952, p. 264) say, of "porphyrite", "A synonym (for microdiorites) which is still widely used is "porphyrites"; . . . in view of the several quite different usages, it is highly desirable to drop the term in favour of porphyritic microdiorite". "Porphyry" is not mentioned as a rock name in its own right. Harker (8th revision, 1954, by Tilley and Nockolds, of the 7th, 1935, edition) has a chapter headed "Porphyries and Porphyrites" which begins (p. 105) "The rocks which are for convenience grouped together in this chapter belong to various hypabyssal types of *intermediate* chemical composition"—"According as the dominant constituent is an alkali feldspar or a soda-lime feldspar, they fall into two families, to be distinguished as porphyries and porphyrites respectively". However, "porphyry" is never used alone in the following text: it is always combined, as "syenite-porphyry", "orthoclase-porphyry", and so forth. "Porphyrite" may stand alone but "diorite-porphyrite" is used for rocks "most nearly approaching the plutonic".

Holmes (1928) says of porphyry—"A term first given to an altered variety of porphyrite (porphyrites lapis) on account of its purple colour, and afterwards extended by common association to all rocks containing conspicuous phenocrysts in a fine-grained or aphanitic groundmass. The resulting texture is described as porphyritic. In its restricted usage, without qualification, the term porphyry usually implies a hypabyssal rock containing phenocrysts of alkali feldspar, though in the field it is generally allowed a wider scope, and commercially it is used for all porphyritic rock". (This is, incidentally, the definition quoted by the "Glossary of Geology and Related Sciences" published by the American Geological Institute, 2nd, 1960, edition).

Tyrrell (1926) uses "porphyry" with a textural connotation only. Thus in British-published petrological texts neither "porphyry" nor "porphyrite" has the status of a consistently defined and widely used rock name.

In "post-classical" German-speaking usage Niggli (1954, p. 510-511) maintains the Rosenbusch nomenclature strictly, with "porphyry" as an "old" equivalent of the younger trachyte, and "porphyrite" similarly equivalent to andesite. For the hypabyssal equivalents (i.e. the "porphyries" and "porphyrites" of Johannsen) he uses "syenite-porphyry" and "diorite-porphyry". This nomenclatural system is strictly and logically pursued, and a "porphyry-porphyrite" is thus the "old" equivalent of a latite, and a "quartz-porphyry-porphyrite" has the same relationship to a rhyodacite. A recent German text (Bentz, 1961) does not include "Porphyr" as a rock name, and defines "Porphyrit" virtually as a pyroxene andesite.

There thus seems to be little evidence to support Johannsen's view that outside America "porphyries" are the porphyritic equivalents of the granites. "Quartz-porphyry" fills this position in

British petrography, and Johannsen's own preference essentially conforms with that of such diverse authorities as Rosenbusch, Harker and Niggli: "porphyry" and "porphyrite" are porphyritic chemical equivalents of "syenite-trachyte" and "diorite-andesite" respectively, and are distinguished by the composition of their contained feldspar. It is possible that the use of "porphyry" to denote a rock chemically equivalent to a granite but having phenocrysts in an aphanitic groundmass is characteristic of American usage outside the United States Geological Survey. Thus Stringham (1960, p. 1623) distinguishes between "granite", "porphyritic granite" and "rhyolite porphyry", and suggests that "granite porphyry" as a synonym for the latter should be dropped. The unmodified "porphyry" is apparently chemically equivalent to granite. The problem is not a simple one, however, since "porphyritic rhyolite" is also presumably a valid name, and Stringham (1953) earlier used "granite porphyry" himself.

Western Australia

For the Kalgoorlie area Card* (1898b, p. 18-22) gave a review of earlier work, all of it innocent of the word "porphyry" in any form. He (1898a, p. 192) spoke of the country rock as "a quartz-felspar porphyry" which "may approximate to a granite in places", and also (1898b, p. 40) as "felspar-porphyry". From the general manner of Card's writing he appears to use "porphyry" with textural significance only. Simpson** (1902, pp. 72-75) described two types of "newer eruptives" among the large collection of rocks made by W. D. Campbell and A. G. Maitland during the preceding three years. These include "felspar-porphyry" and "porphyrite"; both are intrusive quartz-free porphyritic rocks, the former with orthoclase and the latter an "intrusive porphyritic diorite"; this suggests that Simpson followed the Rosenbusch distinction closely. In the table of chemical analyses of "felspar-porphyries" they are called simply "porphyries". Gibson (1911, p. 116; and in Simpson & Gibson, 1912) distinguished "porphyrites" and "quartz and felspar porphyries", but gave no clear definitions. From page 629 (the paragraph beginning on line 13) of Thomson (1913) it seems possible that this usage may be Thomson's (see below) rather than Simpson's. Larcombe's (1912) classification of the Kalgoorlie rocks is highly individual. Whichever of his varieties of quartz- andesite would now be called "porphyries", his only rock name to include the word is "felsite-porphyry", a pink dyke-rock with orthoclase phenocrysts. He noted the use of "porphyrite" by other writers but did not apply it to any rock which he examined. The general summary of rock nomenclature by Farquharson (1912, p. 26-27), who was appointed as Petrologist to the Geological Survey of Western Australia in April 1911, shows that he ostensibly used "porphyry" and "porphyrite" in the Rosenbusch sense, but later (Farquharson, 1912, p. 40) gave an incompatible definition based on silica percentage. Thomson (1913) used "albite-porphyry" and "porphyrite" apparently in the belief that he was following Simpson's nomenclature; but he distinguished between "porphyries" and "porphyrites" (p. 654) "chiefly on the presence of hornblende and biotite in the porphyrites, and on the absence of these minerals in the porphyries".

In the same year Feldtmann and Farquharson (1913) provided another departure in nomenclature. Farquharson (p. 56-67), on the basis of a chemical analysis only, classified the Kalgoorlie "porphyries" as "quartz-keratophyres". Feldtmann (p. 13) found this cumbersome and in his section of the bulletin called them all "porphyrites", essentially as a field term, justifying his fusion of "felspar-porphyry" and "porphyrite" (especially of Gibson) by a statement of Gibson's that the two types approach very closely and appear to be closely connected. He* later used (Feldtmann, 1916, p. 38-41) a modified version (hornblende-quartz "porphyrites" and "albite-porphyrites"—roughly equivalent to Simpson's "porphyrites" and "albite-porphyries") of this nomenclature but Farquharson (1915) later abandoned "quartz-keratophyre" and for the similar rocks of the Meekatharra area (Farquharson, 1916, p. 217-219) adopted a mineralogical subdivision of "porphyry" which included "hornblende-quartz porphyry or porphyrite". Honman (1916, p. 26-32) apparently used a division of the hypabyssal rocks into "quartz porphyry" and a more basic "porphyrite" but it is difficult to make sense of the nomenclature in this bulletin between Honman's own ideas and the intercalated descriptions and names of Farquharson (e.g. "quartz-porphyrite").

Stillwell (1929, p. 19) made a completely fresh start with the following division:—

"4. Porphyrite Series.
- (a) Porphyrite.
- (b) Albite Porphyry.
- (c) Basic Porphyrite."

The basis of this subdivision appears to be (Stillwell, 1929, p. 30) the silica percentage in chemical analyses. However, in many places in the text of this bulletin (p. 29, line 11; p. 31, line 9; p. 50, lines 31-32; p. 70) Stillwell used "porphyry" as a generic term to cover any or all of these varieties, and on page 66 wrote "The acid and basic porphyries are presumably acid and basic differentiates from the magma which gave rise to the large mass of porphyrite." Prider (1941) found no fault with this criterion, but only referred to the last two divisions, and accepted quartz dolerite, basic porphyrite and albite porphyry as differentiates of increasing acidity from the same magma. Matheson (1947, p. 74-75) established a "Porphyry-Porphyrite Series" for the Coolgardie area. In this series the "normal type of porphyry is granitic in composition". McMath (1947; 1948) accepted the same nomenclature, but later wrote (1953, p. 74) of the "Porphyry-Porphyrite Series"—"In view of the petrogenetical implications of this term, it is felt that, until sufficient chemical and petrological data are available, these rocks are better referred to as 'Pre-folding Porphyritic Minor Intrusives' ". In them "The essential minerals" are "albite, quartz, and subordinate amounts of biotite and muscovite". Ward (1953, p. 302) maintains the use of "Porphyry-Porphyrite Series" in the second part of the same bulletin.

To summarise Kalgoorlie area development of nomenclature: Card (1898a; 1898b) used "porphyry" as a textural suffix without precise taxonomic significance. Simpson (1902) followed Rosenbusch's distinction between "porphyry" and "porphyrite" (both quartz-free rocks) on feldspar composition. Thomson (1913) disregarded feldspar, and distinguished the two rocks on mafic minerals. Feldtmann and Farquharson (1913) were inconsistent in their usages and Stillwell (1929) made a fresh start with a distinction based on silica percentage. Prider, Matheson and McMath all followed this nomenclature in spirit. Current usage at Kalgoorlie seems to have reverted to something close to Card's, and to be roughly as follows:

> *Porphyry*.—A more or less structureless, homogeneous, porphyritic rock, variously pink, white, brown or grey in colour, in which phenocrysts of feldspar, or quartz, or both, are set in an aphanitic matrix. It usually forms intrusive bodies of greatly variable size and shape, and is frequently sheared and metasomatically modified. Most porphyries are chemically and mineralogically equivalent to tonalite, granodiorite or granite.

* A Royal School of Mines (London) graduate who probably learnt his petrology from Professor W. W. Watts.

** E. S. Simpson graduated B.E. in mining and metallurgy from Sydney University and came to Western Australia in 1897 at the age of 22. Probably he was familiar with Harker (1895) on matters of igneous rock nomenclature.

* Feldtmann (1916) acknowledges Farquharson's influence on his nomenclature. Farquharson probably adopted finally Rosenbusch's equivalences of granite-*quartz porphyry*-rhyolite, syenite-*porphyry*-trachyte, tonalite-*quartz porphyrite*-dacite and diorite-*porphyrite*-andesite, but he failed to make his nomenclature clear or to impress it on his contemporaries.

Porphyrite.—Porphyry, as defined above, but lacking phenocrystic quartz and with much hornblende or its derivatives (mainly chlorite).

Some Chemical Features of "Porphyries" and "Porphyrites"

It has been shown that various criteria have been used to differentiate between "porphyry" and "porphyrite"; the two most important are silica percentage and feldspar composition. The recent compilation by Joplin (1963) of chemical analyses of Australian igneous rocks includes analyses of 48 "porphyries" and 31 "porphyrites", ignoring modifying prefixes. Certain chemical features of these two groups are discussed below and illustrated in Plate 27 as a basis for examining to what extent they reflect the distinguishing criteria.

From figure A, a percentage frequency plot of silica content, it is clear that both "porphyries" and "porphyrites" have normal distributions with peaks separated by about 12% SiO_2 and an overlap of about twice this. It would be possible to make a separation at about 65% SiO_2 without modifying the *de facto* usage beyond recognition. The alkalis are similarly plotted in figures B and C. While Na_2O distribution is surprisingly similar for both groups K_2O differs markedly, and the ratio K_2O/Na_2O should be a useful index which would reflect the feldspar composition. The distribution of this ratio is shown in figure D. Evidently both "porphyry" and "porphyrite" have an approximate log-normal distribution, and an arbitrary division could to made at about $K_2O/Na_2O = 1$ to rationalise the *de facto* usage. However, it is not known from figures A and D to what extent the rocks in each group which transgress the postulated dividing lines are common to both diagrams. In other words: is a rock with silica higher than 65% likely also to have K_2O/Na_2O ratio greater than 1, and *vice versa*? To answer the question the ratio K_2O/Na_2O is plotted against SiO_2 in figure E, separately for "porphyries" and "porphyrites", together with the mean values (mainly Daly's; some Johannsen's; all taken or calculated from Johannsen, 1932, 1937) of the four main families of acid and intermediate rocks.

From figure E and the foregoing diagrams the following generalisations appear to be valid:—

(1) Although there is a tendency for rocks called "porphyry" to be richer in silica and relatively richer in potash than soda than those called "porphyrite" there is a large overlap between the two groups which is not reflected in the *de facto* nomenclature.

(2) A high silica content does not necessitate a high K_2O/Na_2O ratio.

(3) A high K_2O/Na_2O ratio is present only in silica-rich rocks.

If in figure E arbitrary divisions are made at $SiO_2 = 62.5\%$ and $K_2O/Na_2O = 1$ (this point is shown by a cross) and if the four quadrants are called syenite, granite, diorite and tonalite, then of all 79 Australian igneous rocks called "porphyry" or "porphyrite":—

(1) None fall in the syenite quadrant.

(2) 48% fall in the granite quadrant; 84% of these have been called "porphyry".

(3) 22% fall into the diorite quadrant; 88% of these have been called "porphyrite".

(4) 30% fall into the tonalite quadrant; 58% of these have been called "porphyry" and 42% "porphyrite".

Recommendations

Porphyries (in the Kalgoorlie sense defined earlier p. 97) are intractable rocks to classify in that they are often too fine-grained for effective mineralogical classification and often too altered for chemical classification (apart from the inherent disadvantages of this). It appears from the previous section that, chemically, Australian rocks which have been described in publications as "porphyry" or "porphyrite" fall naturally into 3 groups: silica-rich and potassic "porphyries", silica-poor and sodic "porphyrites", and a third group consisting of "high-silica porphyrites" or "low-potash porphyries" which correspond to tonalites and have no separate and commonly used name.

In view of the overlap between all three groups and the poor correspondence between them and the *de facto* nomenclature it is recommended that the term "porphyrite" be dropped, and that "porphyry" be retained and defined as *an acid or intermediate intrusive or extrusive igneous rock containing phenocrysts in an aphanitic matrix; usually chemically equivalent to granite, tonalite or diorite.* It is so used hereunder.

To distinguish the various types "granite porphyry", "tonalite porphyry" and "diorite porphyry" seems to me superior to the "rhyolite porphyry", "dacite porphyry" and "andesite porphyry" preferred by Stringham (1960, p. 1623) because the names rhyolite, dacite and andesite carry a stronger implication of extrusion than do the other names of intrusion. Thus in the suggested nomenclature "granite porphyry" could be called "porphyritic rhyolite" if known to be extrusive. With Stringham's suggestion the distinction between "rhyolite porphyry" (intrusive) and "porphyritic rhyolite" (same rock but extrusive) appears finer and more confusing than that he objects to between "granite porphyry" (intrusive or extrusive; aphanitic matrix) and "porphyritic granite" (intrusive; macroscopically granular matrix).

Qualified names such as "quartz porphyry" should be avoided as misleading, since most porphyries contain quartz in the matrix if not as phenocrysts, and it has yet to be demonstrated that the appearance of conspicuous phenocrystic quartz is more closely related to silica percentage than to the cooling history of the particular rock.

SOME PETROGRAPHIC FEATURES AND PROBLEMS OF PORPHYRY

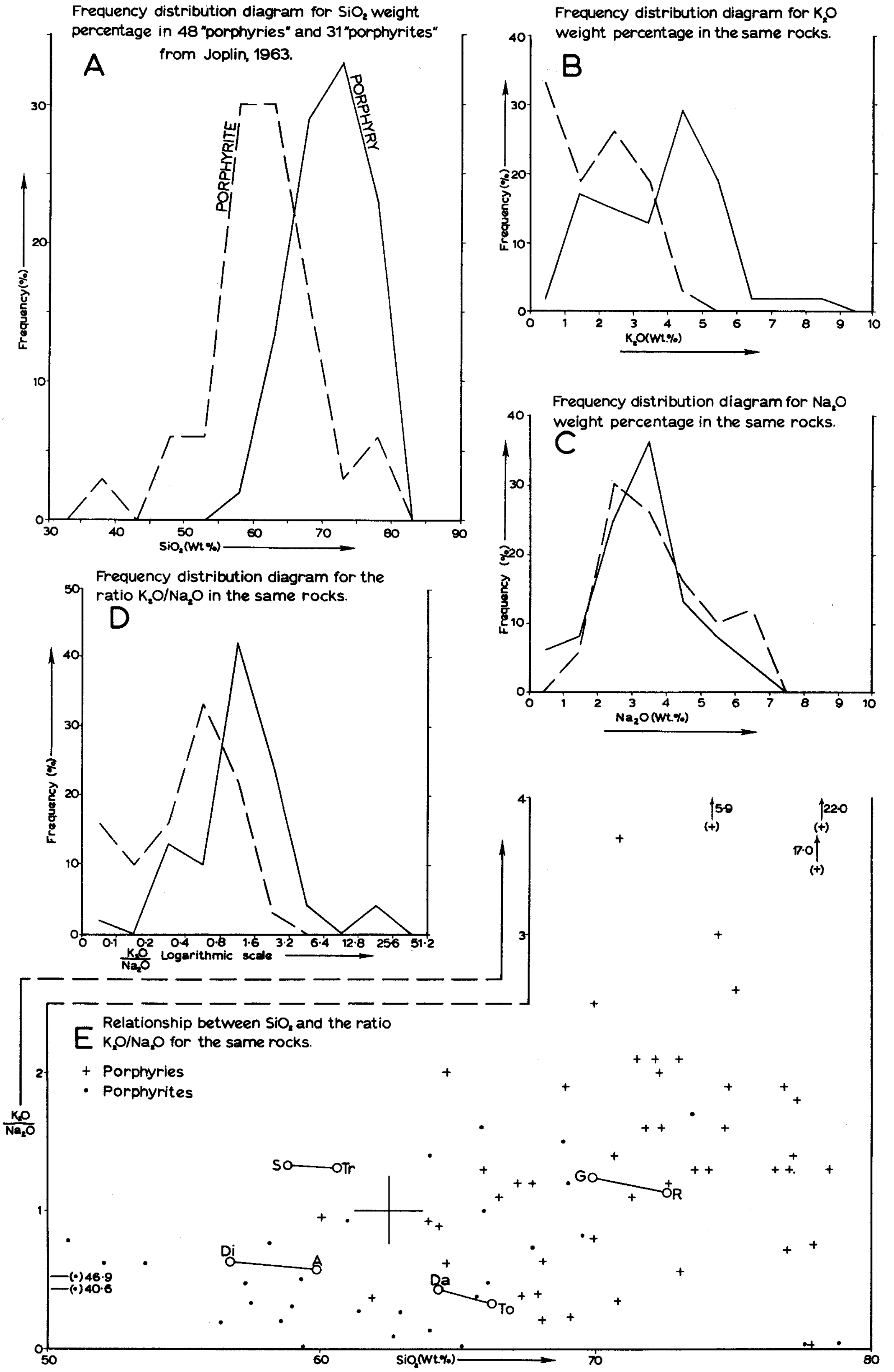
Occurrence and Petrography

Porphyry occurs commonly in the older Precambrian rocks (Pilbara and Yilgarn blocks) of Western Australia, mainly in elongate planar concordant bodies tens of feet thick which may variously be dykes, sills or flows. Those bodies which are intrusive have been injected at various stages of the local folding. The smaller bodies have sharp margins but in many places margins are diffuse and raise controversial problems which are noted below. In the smaller bodies at least, the phenocrysts persist to the margin and there is no sign of either chilling or contact effects. Irregularly shaped bodies several miles long and several hundred feet thick are known. The description of porphyry below is compiled from many specimens and thin sections from widely scattered localities.

In hand specimen the rock is tough, compact, homogeneous and structureless, and may be black, white, brown, pink, red or grey. Rounded phenocrysts of clear glassy quartz or euhedral white or pink phenocrysts of feldspar, between 2 and 10 mm. across, are evenly distributed through the aphanitic matrix, and form between 10 and 50 per cent. of the total volume. Quartz and feldspar phenocrysts may both be present.

In thin section the feldspar phenocrysts are usually albite or oligoclase. Any or all of these in a slide may show some intergrowth with orthoclase or microcline, or phenocrysts of plagioclase and potash feldspar may co-exist but in separate phenocrysts. Quartz phenocrysts, if present, invariably have the slightly corroded euhedral (bipyramidal) shapes typical of acid lavas. Biotite, muscovite, chlorite, amphibole, iron oxides and calcite are usually present but rarely in great volume; biotite in particular often occurs in vaguely pseudomorphous clusters. The matrix in which all the phenocrysts lie consists of an even-grained mosaic mainly of quartz, usually with some potash feldspar or plagioclase, and rarely entirely of feldspar. The

DIAGRAMS (A-E) SHOWING CERTAIN CHEMICAL FEATURES OF "PORPHYRIES" AND "PORPHYRITES"



Circles mark average compositions. A = andesite Da = dacite Di = diorite G = granite R = rhyolite S = syenite To = tonalite Tr = trachyte Lines join extrusive and plutonic taxonomic equivalents.

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average grain diameter of this mosaic is about 0.025 mm. and there is often some sericite, biotite, or amphibole of similar grain-size disseminated through it.

Problems

Two major problems of porphyries are noted briefly below: their post-crystallisation alteration and their relationship to sedimentation.

In all porphyries studied there is some evidence of post-crystallisation degradation. This is roughly divisible into three types which are rarely clearly separable and are certainly to some extent gradational: early (hydrothermal?) modification, mechanical modification (shearing), and late bulk replacement by particular minerals. The first type is most easily traceable in the feldspar phenocrysts. The least altered of these are either oligoclase (An_{20-30}) with oscillatory zoning, alkali feldspar (potassic oligoclase) with or without broad zoning, or microcline. The first two types have a preference for simple basal plane (mainly Manebach) twinning. They are distinguishable mainly during breakdown: the oligoclase alters to albite (An_{2-5}) with lamellar albite twinning while potassic oligoclase alters either to chessboard albite or to one or other of a great number of textural varieties of albite/orthoclase intergrowth. Porphyry is very commonly sheared, with pieces of phenocryst displaced along parallel shear planes which give a close directional orientation to the whole of the matrix material. The last type of modification is most commonly either silicification or carbonation; in both processes the original textures show clearly as ghost outlines within either even cherty quartz of average grain diameter 2-5 microns or rather coarse calcite.

The textural evidence for these two latter processes is clear but their significance is not. Silicification is often spoken of as a surface phenomenon but is certainly not closely related to existing topography. The problem associated with shearing is whether (and, if so, why) porphyry during folding accommodates stress preferentially by a greater internal deformation than the enclosing rocks. The problem in the early modifications is to what extent the changes reflect internal rearrangement of the components or bulk changes in composition; are tonalite porphyries ever leached granite porphyries?

Porphyry bodies often have a general field association with conglomerates composed entirely of rounded cobbles of porphyry in a matrix of clastic porphyry material. The apparent gradation of porphyry into such porphyry-conglomerates and the gradation of these into polymict conglomerates has led to the suggestion of a "porphyritisation" process by which conglomerate is metasomatically altered to porphyry (Sofoulis, 1962). Two main points of petrographic evidence suggest that porphyry-conglomerate is derived from porphyry rather than *vice versa*. Firstly, much of the oscillatory zoning of feldspar phenocrysts of porphyries is of a type characteristic of extrusive rocks which are undoubtedly of straightforward magmatic origin; it can be explained by crystallisation in a rapidly cooling magma (Trendall, 1962) and has never been described in metasomatically grown feldspars. Secondly, although truncated phenocrysts are common at the edges of cobbles in porphyry-conglomerates I have never seen one growing across a cobble edge. These two observations fit with a hypothesis that such porphyry-conglomerates are breakdown products of lavas or sills in which the rounding of the cobbles took place internally during bulk flow, possibly quite soon after emplacement. Many greywackes associated with porphyries have abundant clastic albite closely resembling (in twinning, weathering, inclusions, grain-size) that of the porphyries; the quartz also shows minor points of similarity. It is possible that such greywackes may be the ultimate detrital product of bulk flow of porphyry with or without admixed terrigenous detritus.

It is hoped that this brief review of porphyry as a rock type will focus attention on some of its many puzzling features.

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THE CORRELATIVE VALUE OF MICROPLANKTON IN THE CRETACEOUS OF THE PERTH BASIN, W.A.

By H. S. Edgell

INTRODUCTION

The occurrences of fossil microplankton in the Southern Hemisphere has been reported only in the last decade. These very small, planktonic microfossils were first noted in Australia by Deflandre and Cookson (1954), who observed them in sediments ranging from Cretaceous to Upper Miocene. Development of palynology has given a great impetus to the study of microplankton, since the latter includes many groups with acid insoluble shells. These are often found in macerated residues prepared for spore and pollen examination.

In the relatively undeformed and unaltered Cretaceous sediments, which border the western margin of Australia, a great diversity of microplankton genera and species has been identified in recent years. This is largely due to the detailed studies by Drs. Cookson, Deflandre and Eisenack (see references) of sedimentary samples obtained in drilling for oil and water in the Perth, Carnarvon and Canning basins. From a taxonomic viewpoint studies of Cretaceous microplankton in Western Australia are far advanced and 40% of all Cretaceous dinoflagellate genera have been originally described from here.

The great variety of distinctive genera and species of microplankton known from the Cretaceous of Western Australia, together with the restricted stratigraphic ranges of many forms, make them an ideal group for subsurface correlation. As the group is planktonic and widely distributed by ocean currents, the same genera and species can be recognised on an inter-continental scale. At least three-quarters of the definite dinoflagellate genera found in the Cretaceous of northern Europe also occur in the Cretaceous of Western Australia.

Although primarily confined to marine or brackish sediments, fossil microplankton provide a useful means of correlating wells for water in the Perth Basin. Microplankton species, principally those belonging to the dinoflagellates and hystrichosphaerids, enable more detailed subdivision than is possible with long-ranging species of spores and pollen. The latter groups are also strongly influenced by ecological changes and past floral provinces.

DEFINITION OF MICROPLANKTON

Microplankton includes those microscopic, floating organisms which abound in the oceans, both past and present, and form the food of larger animals. The majority of these are unicellular and belong to the Protista. Certain kinds of microplankton secrete a hard, mineralised shell, while others have only organic membranes or thecae. Those with mineralised shells include the Foraminifera, Radiolaria, diatoms and coccolithophorids and have been widely studied by micropalaeontologists. The forms with organic, cellulosic membranes, or thecae, are very small and acid insoluble. They include the dinoflagellates, hystrichosphaerids and other groups of uncertain affinities with membranous-tests. The term microplankton is now generally used in palaeontology only for the latter group with cellulosic shells or thecae. Due to their very small size and the insolubility of their shells in powerful reagents, such as hydrofluoric acid, special methods of preparation and examination are required.

METHODS OF PREPARATION

The most effective method of separating microplankton from the enclosing sediment has proved to be dissolution of all siliceous rock material in boiling hydrofluoric acid of 30% to 50% strength. The acid resistant, cellulosic wall material of the micro-organisms is not dissolved and plant material is likewise not affected. After repeated centrifuging, treatment with Schulze's solution and neutralisation, a small residue is obtained. This concentrate is then stained with a few drops of Safranin-Y and mixed with a small amount of glycerol, or other mounting media. The microplankton content can then be examined on standard slide preparations under transmitted light with a high power, binocular microscope. Magnifications in the range 150 × to 1,500 × are necessary in the search for, and identification of microplankton species.

METHODS OF IDENTIFICATION

Dinoflagellates are the group of fossil microplankton about which most is known at present. Criteria for their classification and identification consist broadly of morphology, size, variation and position of the pylome or ruptured opening of the theca. The structure of the dinoflagellate shell is complex and consists of a tabulate theca divided by a transverse furrow, or girdle, into two opposing parts. These are termed the epitheca, or apical part, and the hypotheca, or antapical part. The latter generally shows a longitudinal furrow, in which the flagellae were situated, and this forms a base line for a system of plate enumeration. An apical projection and antapical horns are often developed. All the above features are used in identifying dinoflagellate species. The hystrichosphaerids and forms of uncertain affinities are distinguished on the basis of overall shape, size, wall structure and ornamentation. Distinctive morphology is the primary consideration, including character of the protruberances and the existence of more than one enclosing membrane.

In addition to the tabulate, motile dinoflagellates and the hystrichosphaerids with protruberances and absence of opening, it is now realised that there is a confusing third group. These are dinoflagellate cysts, representing the resting stage of dinoflagellate species. The encysted forms may include many genera previously referred to as hystrichosphaerids (Evitt, 1961).

Apart from certain clear dinoflagellate families, such as the Deflandreidae, Gonyaulacidae and Gymnodinidae, the taxonomic relationships of a multitude of other forms of microplankton are not yet resolved. Thus many of the present named species are purely morphologically distinct, organic bodies of ultramicroscopic size, found in older sediments.

PREVIOUS WORK ON MICROPLANKTON.

Previous published work on Cretaceous microplankton is very limited, being based on the studies of less than ten research workers throughout the world. Fortunately, three of the most active contributors, Cookson, Deflandre and Eisenack (see references), have described many genera and species from the Cretaceous of Western Australia and carefully recorded occurrences of known European forms. Most of this knowledge of our Cretaceous microplankton has come from publication of occurrences of species in wells drilled for oil or water in the marginal basins of Western Australia, particularly the very numerous bores for water in the Perth Basin.

THE STRATIGRAPHIC APPROACH TO MICROPLANKTON STUDIES.

Although much careful descriptive work has been carried out on new genera and species of Cretaceous microplankton, no detailed evaluation has been made of their stratigraphic distribution. The stratigraphic occurrences of new and known forms of microplankton have been recorded carefully in the works of Cookson and Eisenack (see references), as well as in observations by the writer on bores in the Perth and Carnarvon Basins. It is clear that many distinctive species of acid insoluble microfossils have narrowly restricted, vertical ranges, much more so than is the case with associated species of spores and pollen grains.

Many of the occurrences of microplankton, especially in the Carnarvon Basin, are accurately dated by their association with Foraminifera, which are elsewhere used as index fossils for stages of the Cretaceous System. Detailed age subdivision of the Cretaceous in this area has been established by the writer 1954, 1957, 1962) on the basis of planktonic Foraminifera and later by Belford (1959, 1960) on general foraminiferal assemblages. It is fortunate that Cookson and Eisenack have carried out microplankton studies on wells already dated by Foraminifera, such as the Brickhouse bore and Rough Range wells. This enables us to establish the time-ranges of microplankton species in the Carnarvon Basin. As a consequence the age of poorly fossiliferous Cretaceous formations in the Perth Basin can now be given. Correlation within some stratigraphic units, such as the South Perth Formation, is also possible on the basis of microplankton species of restricted ages.

PROBLEMS OF CRETACEOUS CORRELATION IN the PERTH BASIN

The sediments deposited during the Cretaceous Period in the Perth Basin are predominantly sands and siltstones. Some interbedded shales are present, as well as odd glauconite beds, but calcareous sediments carrying marine invertebrates are rare. Consequently, the dating and correlation of Cretaceous sequences up to 2,000 feet thick encountered in water bores in the Perth Basin present a problem. The only adequately-dated formation has been the Gingin Chalk, near the top of the local section, which is only 70 feet thick and contains Santonian crinoids such as *Marsupites* and *Uintacrinus* (Withers, 1924, 1926).

Lithological units encountered in nearby bores often show no great similarity. The presence of poorly sorted grains, fresh feldspars and common carbonaceous material shows that deposition was predominantly paralic, with intermittent continental phases. There is frequently an interfingering of lithostratigraphic units within a short distance to which many irregularities in aquifer yield may be attributed.

In the Perth Metropolitan area Eocene siltstones of the Kings Park Shale cannot be readily distinguished from the underlying Cretaceous Osborne and South Perth Formations on the basis of lithology alone. Nor can the latter formations be distinguished from the Jurassic Claremont Sandstone, which often contains thick shale and siltstone intervals in its upper part. Palaeontological work on the Kings Park Shale by Parr (1938) and Coleman (1952) showed that it contained Foraminifera of Middle and Late Eocene age. However, only a few, insignificant, benthonic Foraminifera have been observed in the Osborne and South Perth Formations.

Since 1957, palynological work by B. E. Balme has allowed a general distinction between major formations. However, the primarily endemic species of spores and pollen grains provide little basis for correlation with European stages. A more detailed subdivision and correlation of local Cretaceous formations may be attained by using the restricted ranges of microplankton species.

Considerable lateral variation can be seen in the thickness, lithological character and stratigraphic nomenclature of Cretaceous formations of the Perth Basin. This is to be expected in a narrow sedimentary basin at least 800 miles long, where coarse paralic and continental sediments predominate. Cretaceous strata, in most areas of the basin, are subhorizontal or shallowly dipping and are generally covered by clays or coastal limestones of Quaternary age.

Although higher Cretaceous formations crop out in the Gingin area, the major part of the Cretaceous sequence in the Perth Basin is known from water bores and exploratory wells for oil. A stratigraphic diagram (Plate 28) summarizing the lithological units of the Cretaceous in parts of the Perth Basin is given as a background to the stratigraphic distribution of microplankton species. This diagram shows only published lithostratigraphic names given by Fairbridge (1953) and McWhae and others (1958).

In the northern part of the Perth Basin (i.e. the Geraldton-Three Springs area) only the lower part of the Cretaceous System is represented by the Yarragadee Formation. This is a primarily continental unit of sandstones and micaceous siltstones, which extends down to the Upper and Middle Jurassic. There are no records of microplankton in the Yarragadee Formation. Its continental facies, and thickness (from 51½ feet to 490 feet in the two reference sections nominated by McWhae and others, 1958) do not warrant its usage in the vicinity of Perth.

The Gingin—Moora area, in the central part of the Perth Basin, contains surface exposures of a clearly defined sequence of Upper Cretaceous marine formations. They are thought to rest unconformably on thick Lower Cretaceous-Jurassic, continental sediments of the Yarragadee Formation.

The Upper Cretaceous formations in the Gingin-Moora area contain many restricted species of microplankton. These have come largely from fresh samples obtained in seismic shot holes and stratigraphic wells drilled by the West Australian Petroleum company.

In the area of Perth itself, most of the higher Cretaceous formations have been removed by erosion. The marine Osborne Formation is generally the highest stratigraphic unit in the local Cretaceous succession and is of approximate Cenomanian age. It is underlain conformably by a thick, dominantly marine, Lower Cretaceous sequence. This is the South Perth Formation (up to 1,224 feet thick in the Leederville Valley Bore), which contains frequent microplankton species. These provide a series of Lower Cretaceous microplankton zones to link up with the Upper Cretaceous zonation deduced from the Gingin and Carnarvon Basin successions.

Lithologically, the South Perth Formation consists of interbedded sandstones, dark sandy siltstones and claystones with occasional glauconite, thin carbonaceous beds and minor pyrites. A large number of bores for water penetrate this formation in the Perth Metropolitan Area. Fairbridge (1953), proposed a twofold division into an upper, predominantly arenaceous unit, known as the Leederville Sandstone, and a lower argillaceous unit termed the South Perth Shale. This subdivision has been followed in recent years in detailed correlations of the metropolitan Cretaceous strata by West Australian Petroleum geologists (Pudovskis, 1961).

Bores encountering the South Perth Formation within a 50 mile radius of Perth do not always show these two distinct stratigraphic units within the South Perth Formation. Water bores drilled by the West Australian Mines Department during 1961-62, particularly at Byford and Mandurah, have penetrated considerable thicknesses of Lower Cretaceous strata. Subsurface correlation by lithology, within these sequences of the South Perth

Formation, has proved inadequate. This is probably due to rapid, lateral facies changes. Correlation based on microplankton species with restricted time-ranges provides a partial solution to these difficulties.

In the southern part of the Perth Basin there is no known development of Upper Cretaceous sediments, although most of the Cretaceous rocks are obscured by extensive Quaternary covering strata. Deep water bores such as those drilled at Dardanup and Abba River No. 1 have penetrated up to 1,700 feet of dark siltstones and fine sandstones with frequent carbonaceous material and occasional conglomerate beds. These form the mainly continental Capel River Group (Fairbridge, 1953), ranging from Lower Cretaceous to Upper Jurassic. The dating of this group is based on spore and pollen identifications by Balme (1957). However, marine intercalations containing microplankton occur in the Capel River Group and an interfingering of marine and non-marine facies has been observed in Laporte No. 5 water bore. Although only a few species of microplankton have been recognised to date in the wells drilled by the West Australian Mines Department in the vicinity of Australind and Bunbury, they may give a more accurate age determination of certain horizons.

Within the upper part of the Capel River Group, from Australind to near Busselton, various wells have penetrated an extensive, tholeitic, basalt flow (Edwards, 1938) up to 280 feet in thickness. This is the Bunbury Basalt which forms an important aquaclude at Australind and Bunbury. It occurs above beds which can be dated by microplankton as Aptian-Neocomian and below strata whose microflora is Aptian or older (according to the spore and assemblage ranges given by Balme 1957, 1962 and Cookson and Dettman, 1958). The age of this basalt flow is thus not Tertiary as suggested by Fairbridge (1953), or Upper Jurassic-Lower Cretaceous (Balme in McWhae and others, 1958), but definitely Lower Cretaceous and possibly high in the Neocomian or post-Neocomian.

A subdivision of the Capel River Group was given by Fairbridge (1953) who listed the following descending formations:—

(1) Donnybrook Sandstone,
(2) Blackwood Shale,
(3) Fly Brook Shale,
(4) Warren River Sandstone.

The sequence and extent of these formations are not well-established, although Balme (1956) demonstrated an Early Cretaceous age for the Donnybrook Sandstone, while the writer has found the Fly Brook Shale to be Late Jurassic. These findings are based on spore and pollen analysis. Water bores drilled recently at Australind have not shown clear equivalents of the Donnybrook Sandstone and Blackwood Shale in the Cretaceous sequence. although these formations were named originally for the southernmost part of the Perth Basin.

The main knowledge of Cretaceous microplankton and its application in Western Australia is in the Perth Basin, between latitudes passing through Jurien Bay in the north and Mandurah in the south. In the northern and southernmost parts of the basin detailed correlation by microplankton is precluded by the mainly continental facies of the Yarragadee Formation and Capel River Group. Most of the records and identifications of Lower Cretaceous microplankton species are from very numerous bores in the vicinity of Perth.

THE STRATIGRAPHIC DISTRIBUTION OF CRETACEOUS MICROPLANKTON IN THE PERTH BASIN

More than 100 different species of microplankton are now known from Cretaceous sediments of the Perth Basin. The vertical distribution of the species in known sequences shows that there are at least five stratigraphically successive assemblages. They range from the lower part of the South Perth Formation to the Poison Hill Greensand. Microplankton characteristic of the uppermost Cretaceous (Maestrichtian) may still be found in uneroded sediments elsewhere in the Perth Basin. However, there is apparently a general hiatus above the Campanian in the basin. In the Perth Metropolitan Area, the Eocene Kings Park Shale rests unconformably on lower, or middle Cretaceous strata, which are interpreted as an eroded Cretaceous land surface.

A descending biostratigraphic sequence of Cretaceous microplankton assemblages for the Perth Basin and adjacent areas, as related to the major lithological units, is shown in the accompanying table.

TABLE 1.—THE SEQUENCE OF MICROPLANKTON ASSEMBLAGES IN THE CRETACEOUS OF THE PERTH BASIN AND PROPOSED ZONATION

ZONATION		CHARACTERISTIC MICROPLANKTON SPECIES		LITHO-STRATIGRAPHIC UNITS
Zone	Subzone	Grouped as microplankton assemblages		
Deflandrea serratula	....	Deflandrea macrocysta, D. pellucida, D. serratula, D. nucula, Nelsoniella aceras, Cymatiosphaers pterota, Odontochitina porifera.		Poison Hill Greensand
Deflandrea echinoidea	....	Deflandrea acuminata, D. balmei, D. echinoidea, Diconodinium multispinum, Gymnodinium westralium, Odontochitina cribropoda, Nelsoniella semireticulata, Palaeohystrichophora infusoroides, Aiora fenestrata, Xenikoon australis, Hystrictrosphaeridium sriatoconus.		Molecap Greensand
Gonyaulax cassidata	Diconodinium tenuistriatum	Ascodinium acrophorum, Diconodinium tenuistriatum, D. inflatum, Ginginodinium spinulosum, Hystrichodinium alatum, Lecaniella margostriata, L. dictyota, Microdinium ornatum, Odontochitina striatoporifera, Pseudoceratium ludbrooki, Schizocystia rugosa, S. Laevigata, Stephodinium australasicum.	Codonia campanulata, Gonyaulax edwardsi Gonyaulax cassidata, Paleoperidinium castanea	Osborne Formation (upper part)
	Aptea cf. polymorpha	Aptea cf. polymorpha, Cyclonephelium membraniphorum, Pterodinium cornutum, P. Magnoserratum.		Osborne Formation (lower part)
Dingodinium cerviculum	....	Cyclonephelium ? attadalicum, Dingodinium cerviculum, Horologinella lineata.	Gonyaulax diaphanis Gonyaulax hyalodermopsis	South Perth Formation (upper part)
Muderongia mcwhaei	....	Gymnodinium attadalense, Apteodinium conjunctum, Muderongia mcwhaei, Pseudoceratium tetracanthum.		
Wetzeliella ? neocomica	....	Wetzeliella ? neocomica, Gonyaulax muderongensis Pseudoceratium turneri.		South Perth Formation (lower part)
***Deflandrea* sp. nov.**	....	? Deflandrea sp. nov., Hystrichosphaeridium ramuliferum		

This biostratigraphic sequence is based largely on identifications and recorded occurrences given by Cookson and Eisenack (1956, 1958, 1960a and b, 1962) on bore samples from the Gingin and Perth areas. Observations by the writer on samples from recent water bores, such as Balcatta No. 1, Byford Nos. 1 to 5, Gosnells No. 1 and Mandurah No. 1, have confirmed the general sequence of microplankton species. Additional new species and stratigraphically lower assemblages have also appeared, especially in Mandurah No. 1 and the Byford bores. Future investigations may show that the stratigraphic ranges of some species need correction.

STRATIGRAPHIC UNITS OF THE CRETACEOUS IN THE PERTH BASIN

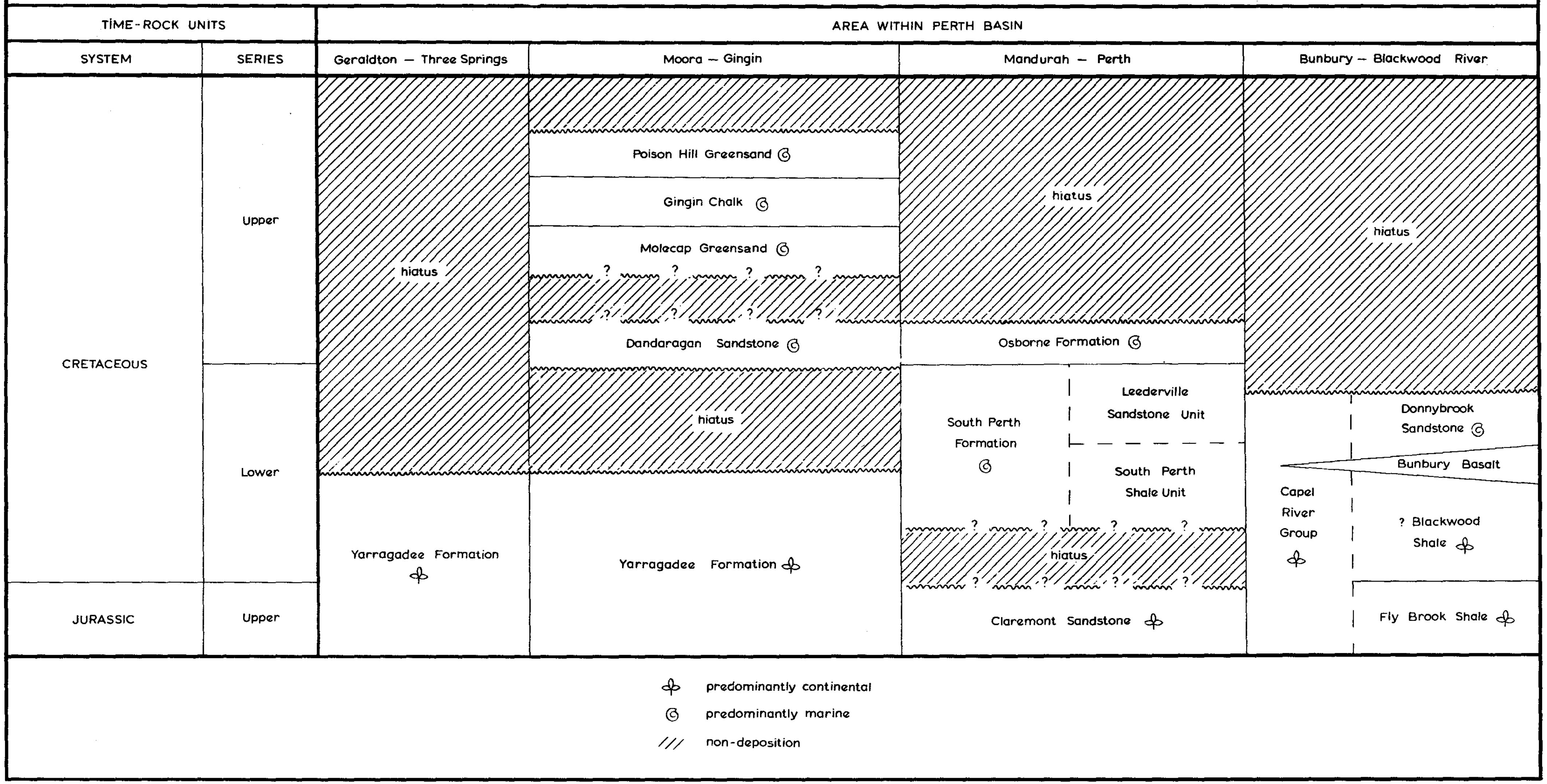
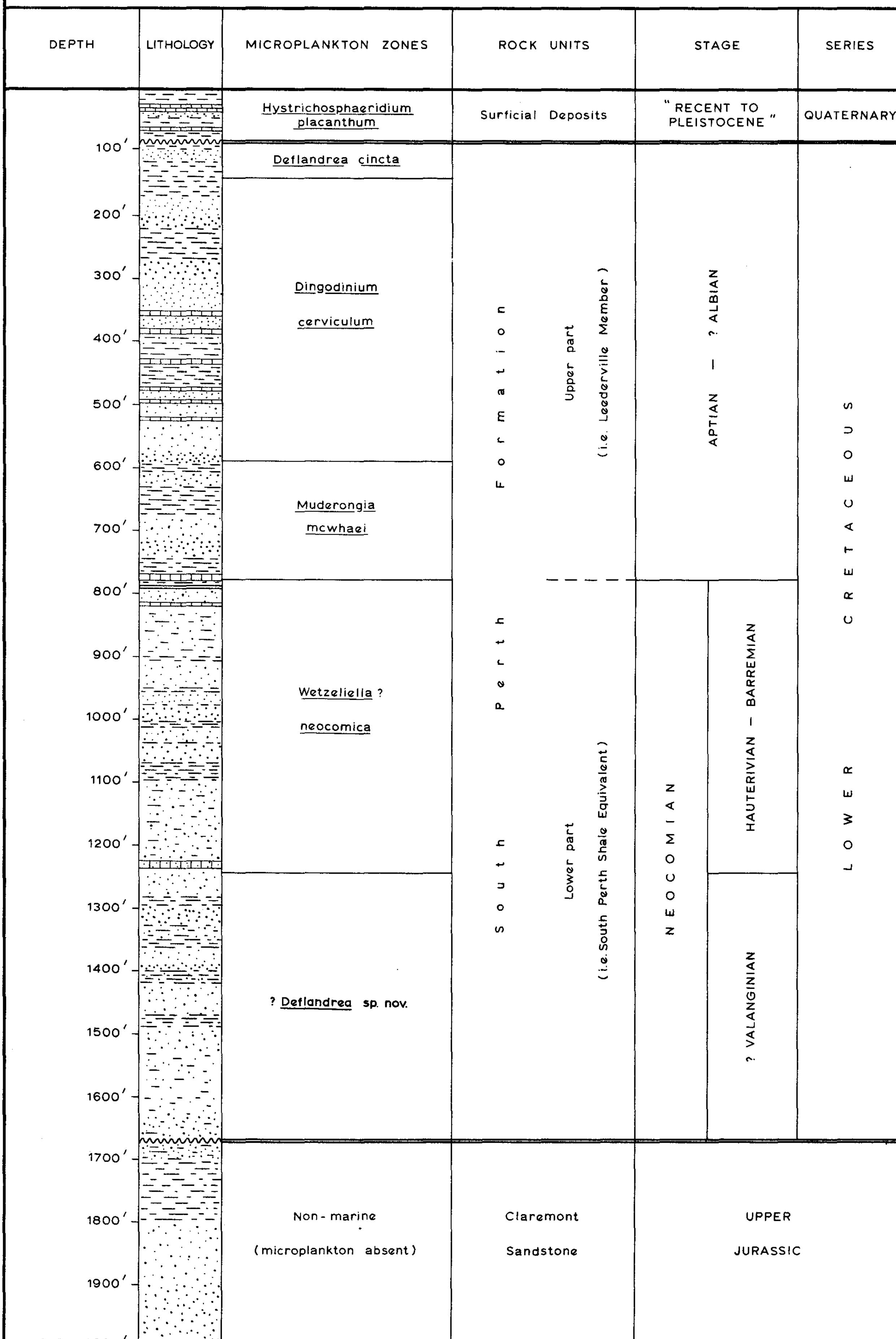


PLATE 28

7757

MICROPLANKTON ZONATION OF MANDURAH No. 1 BORE



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CORRELATION, ZONATION AND AGE RELATIONSHIPS OF CRETACEOUS FORMATIONS IN THE PERTH AND CARNARVON BASINS, WESTERN AUSTRALIA.

SERIES	STANDARD STAGES		FORAMINIFERAL INDEX FOSSILS	CARNARVON BASIN FORMATIONS	MICROPLANKTON ZONATION		CENTRAL PERTH BASIN FORMATIONS		MICROFLORAL ASSEMBLAGES
UPPER CRETACEOUS	MAESTRICHTIAN		<u>Globotruncana</u> <u>contusa</u>	Miria Marl	Zone of <u>Deflandrea</u> <u>serratula</u>				<u>Gleichenia</u> dominant Assemblage
	SENONIAN	CAMPANIAN	<u>Glt</u>. <u>elevata</u>	Korojon Calcarenite			Poison Hill Greensand		
		SANTONIAN	<u>Glt</u>. <u>concavata</u>	Toolonga Calcilutite	Zone of <u>Deflandrea</u> <u>echinoidea</u>		Gingin Chalk		
							Molecap Greensand		
		CONIACIAN							
	TURONIAN		<u>Glt</u>. <u>helvetica</u>						
	CENOMANIAN		<u>Glt</u>. <u>delrioensis</u>	Upper Gearle Siltstone	Zone of <u>Gonyaulax</u> <u>cassidata</u>	Subzone of <u>Diconodinium</u> <u>tenuistriatum</u>	Osborne Formation (upper part)		
				Lower Gearle Siltstone		Subzone of <u>Aptea</u> <u>polymorpha</u>	Osborne Formation (lower part)		
LOWER CRETACEOUS	ALBIAN			Windalia Radiolarite	Zone of <u>Dingodinium</u> <u>cerviculum</u>		South Perth Formation	? Leederville Sandstone	<u>Microcachrydites</u> <u>antarcticus</u> Assemblage
	APTIAN			Muderong Shale	Zone of <u>Muderongia</u> <u>mcwhaei</u>				
				Birdrong Formation				≡ South Perth Shale	
	NEOCOMIAN	BARREMIAN			Zone of <u>Wetzeliella</u>? <u>neocomica</u>				
		HAUTERIVIAN							
		VALANGINIAN			Zone of <u>Deflandrea</u> sp.				
		BERRIASIAN							

7760

PLATE 30

but the presented sequence of microplankton assemblages is consistent in the Perth and Carnarvon Basins and corresponds well with recorded European time-ranges.

A bore at Mandurah to a depth of 2,005 feet, located as a stratigraphic and hydrologic test by the Geological Survey of Western Australia, drilled an unexpectedly thick, Lower Cretaceous sequence of approximately 1,600 feet. This was difficult to relate to the Cretaceous of the Perth Metropolitan Area on the grounds of lithology. However, a distinct subdivision into five microplankton zones was recognised, which gave a fuller biostratigraphic sequence of the Lower Cretaceous than in most other bores in the Perth Basin. The accompanying stratigraphic column of Mandurah No. 1 (Plate 29) shows the relations of microplankton zones deduced from sample examination at close intervals.

In the examination of closely spaced samples from the Cretaceous succession in Mandurah No. 1, no clear subdivision could be recognised on the basis of numerous species of spores and pollen grains. These all appear to belong to the *Microcachrydites antarcticus* Assemblage (Balme, 1962) containing many long-ranging forms.

There is a sharp change of depositional conditions below the Cretaceous strata in the Perth area. In contrast to the mainly marine, or paralic, Cretaceous sediments of the South Perth Formation, the underlying Jurassic deposits of the Claremont Sandstone are continental. This sudden change in the environmental character of the sediments suggests a disconformity between the Upper Jurassic strata and those of the Lower Cretaceous. Appearance of marine conditions and a restricted horizon of marine shells at the base of the South Perth Formation may also indicate a marine transgression in early Cretaceous time and a hiatus between Jurassic and Cretaceous deposition. Thus, the lowermost part of the Cretaceous may not be represented in the central part of the Perth Basin, as is the case in most of the Carnarvon Basin. The microplankton zones proposed for the Cretaceous sequence in the Perth Basin may not, therefore, span the entire Cretaceous System as there is a definite disconformity at the top of the sequence and a possible one at its base. However, the addition of restricted microplankton from higher formations in the Carnarvon Basin provides distinctive microplankton assemblages for all parts of the Cretaceous except the lower Neocomian.

CORRELATION OF MICROPLANKTON WITH THE STANDARD CRETACEOUS TIME-SCALE

(a) *By Associated Index Fossils*

It is difficult to relate the distribution of microplankton species in the Perth Basin with the established series and stage subdivisions of the Cretaceous System. This is due to the character of the local sediments (excepting the Gingin Chalk) and the absence of diagnostic megafossils or other microfossils of restricted ages. Fortunately, the same microplankton sequence, as found in the Perth Basin, occurs with both foraminiferal index species and determinable ammonites and belemnites in the northern Carnarvon Basin. Detailed stage correlation of Cretaceous formations in the latter area have been made on the basis of Foraminifera by Edgell (1954, 1957, 1962) and Belford (1958), as well as by megafossils (Brunnschweiler, 1959).

Many of the forms of microplankton described and identified by Cookson and Eisenack (1957, 1958, 1961, 1962) come from Cretaceous sequences, such as the Brickhouse Bore, already dated by earlier micropalaeontological studies. The inter-regional stage correlation of Cretaceous formations in the Carnarvon Basin is thus well-known. It provides a stratigraphic scale for evaluating the ages of the microplankton species which it contains and most of these occur in similar sequence in the Perth Basin. Microplankton species in the Perth Basin, which are also known from the Carnarvon Basin, establish a time-stratigraphic link between the two areas and enable the dating of poorly fossiliferous formations in much of the Perth Basin. The correlation of Cretaceous formations in the Perth Metropolitan area, with those of the northern Carnarvon Basin, shown in Plate 30, also suggests relationship to standard European stages.

One of the principal conclusions regarding the age of formations in the Perth area, is that considerable Upper Cretaceous strata exist. Most, if not all, of the Osborne Formation belongs to this series, and is generally equivalent to the Cenomanian stage. There is no evidence of Neocomian strata in the Carnarvon sequence, and a general hiatus exists there. A lesser stratigraphic gap probably also occurs in the central Perth Basin between the Cretaceous South Perth Formation and underlying Jurassic Claremont Sandstone. Discovery of the dinoflagellate *Wetzeliella? neocomica* Gocht in the lower South Perth Formation in several bores in the vicinity of Perth indicates the presence of sediments as old as late Neocomian.

Comparison with ages based on microplankton and Foraminifera also shows that the *Microcachrydites antarcticus* Assemblage of Balme (1957, 1962) is confined to the Early Cretaceous, while *Gleichenidites* dominant microfloras of the Osborne Formation are of Late Cretaceous age.

(b) *By Restricted Cosmopolitan Species*

A number of species of Cretaceous microplankton occur both in Northern Europe and the marginal basins of Western Australia. The majority of genera are also common to both regions. To the writer's knowledge, however, no sequence of microplankton zones for the entire Cretaceous System has ever been published for the European area. Thus, it is only possible to recognise species which have been found in certain parts of the European Cretaceous, and suggest that sediments containing them in Western Australia are time-equivalent. This appears valid for a group of small, planktonic organisms which evolved rapidly and are quickly dispersed by ocean currents. Although three-quarters of European Cretaceous genera occur in Australia, only a limited number of European species have been recognised. These appear to have broadly similar time ranges where accurate dating is possible, as in the Carnarvon Basin.

Some Cretaceous microplankton species of intercontinental significance for the correlation of West Australian sediments are discussed below.

1. *Wetzeliella ? neocomica* Gocht (see Plate 31, Figs. 1 and 2) is a distinctive, spinose, dinoflagellate species, with an apical pylome. It was described originally by Gocht (1957) from Upper Hauterivian strata in northern Germany, and has also been recognised by Evitt (1961) from the Neocomian of Pakistan. This form is not assignable to the genus *Wetzeliella* and shows similarities to the Pseudoceratidae (Eisenack, 1961), especially *Muderongia*. It should probably be included with the genus *Muderongia* and has been interpreted as a dinoflagellate cyst by Evitt (1961). In the Lower Cretaceous of the Perth Basin, this species occurs frequently below strata containing Aptian microfaunas and microfloras. Due to its stratigraphic distribution in Europe, Pakistan and Western Australia, *Wetzeliella ? neocomica* is regarded as a Neocomian index fossil.

2. *Pseudoceratium ? tetracanthum* Gocht (see Plate 31, Fig 3) is also described from the Upper Hauterivian of Emsland in north-western Germany. Occurrences of the species in parts of Western Australia have been noted by Cookson and Eisenack (1958). In the Perth Basin succession *P. tetracanthum* occurs mainly higher than *Wetzeliella ? neocomica*, although there is a slight overlap in their ranges. The former species is associated with *Muderongia mcwhaei* and other species regarded as of Aptian or Later Neocomian age. The only difference between *P. ? tetracanthum* and *Muderongia mcwhaei* is a faint girdle in the latter. It has been mentioned by Eisenack (1961) that the two species may be synonymous.

3. *Cymatiosphaera radiata* O. Wetzel occurs frequently in the Osborne Formation and stratigraphic equivalents in the Carnarvon Basin. The species is known from flints of Cenomanian age in northern Germany and probably indicates a similar age in occurrences in the Osborne Formation of the Perth Metropolitan Area.

4. *Palaeoperidinium castanea* Deflandre known from Upper Cretaceous, Senonian or Turonian, flints in France (Deflandre, 1935) is a spiny, spherical species. It has been recorded by Cookson and Eisenack (1962) in numerous wells in the Perth area. Occurrences in the Osborne Formation confirm that this unit is Upper Cretaceous and suggest that the formation may range higher than Cenomanian.

5. *Odontochitina operculata* (O. Wetzel) is likewise known only from Upper Cretaceous (Senonian) deposits in Europe. Records of the species are in the Osborne Formation (King Edward St. Bore, 256 ft. - 295 ft.) and in the Gearle Siltstone of the Carnarvon Basin. They suggest a Late Cretaceous age for these units, rather than an extension of the species into the Lower Cretaceous in Australia, as proposed by Cookson and Eisenack (1958).

6. *Hystrichosphaeridium flosculus* Deflandre has been described from the Senonian flints of the Paris Basin. Its identification in the Toolonga Calcilutite and Molecap Greensand suggests a similar time range in Western Australia, as these formations are known to be Senonian on other fossil evidence.

7. *Palaeohystrichophora infusorioides* Deflandre is also known from the Senonian flints of the Paris Basin and occurs frequently in the Poison Hill Greensand of Upper Senonian (Campanian) age.

USE OF MICROPLANKTON AS FACIES INDICATORS

Microplankton are abundant and represented by a diversity of forms in present day oceans, especially the Dinoflagellata. Together with diatoms they form the major components of marine phytoplankton and as "red tides" may often cause mass mortality of other marine organisms.

Studies of present day dinoflagellates, as summarised by Chatton (1952), show that most are exclusively marine, such as the Gonyaulacidae, Ceratidae and Hystrichodinidae. Members of these families, which are found fossil (e.g., *Gonyaulax* and *Hystrichodinium*) presumably had a similar habitat. Some dinoflagellates also occur in fresh and brackish water, although much less commonly.

The rarer and more selective occurrences of microplankton species in fresh water conditions, leads to the generalisation that their frequent occurrence indicates a marine environment. This is borne out in the Cretaceous sequences of the Perth and Carnarvon Basins, where samples most rich in microplankton also contain other marine fossils, or evidence of marine sedimentation (i.e., glauconite).

The interfingering of exclusively spore-pollen bearing sediments with those also containing microplankton is common in the Perth Basin, and is interpreted as an alternation of marine and non-marine sedimentation.

THE ROLE OF MICROPLANKTON STUDIES IN CURRENT INVESTIGATIONS BY THE GEOLOGICAL SURVEY OF WESTERN AUSTRALIA

The Cretaceous sediments of the Perth Basin contain numerous aquifers of considerable local importance for varied purposes such as town drinking supply, sewerage disposal, irrigation and industry. In past drilling it has been difficult to ascertain to what formation the sediments belonged. It has often been uncertain whether the formations drilled were of Quaternary, Cretaceous or Jurassic age and much reliance has been placed on palynology. More directly, the problem of recognising the same aquifer in adjacent bores has not been resolved by lithology alone. Detailed correlation within the Cretaceous by microplankton can also avoid unnecessary drilling, where the aquifer objective has been penetrated but not realised. In some cases, where a bore is to be abandoned, additional drilling may be recommended to reach a potential water-bearing horizon anticipated at a slightly greater depth on biostratigraphic grounds. Establishment of a sequence of microplankton zones in the Cretaceous of the Perth Basin may permit more precise age determinations and a more detailed correlation between bores.

Several factors restrict the use of microplankton for correlation throughout the Cretaceous of the Perth Basin. These are the continental aspect of sediments in the northernmost and southern parts of the basin, the comparative rarity of specimens in many samples and inadequate knowledge of the time-ranges of many species.

Microplankton studies, however, offer a substantial aid to correlation in the Cretaceous of the central Perth Basin, where there is the greatest demand for subsurface water. Detailed zonation by microplankton also provides a link in correlation of formations between the Perth and Carnarvon Basins, as well as a better understanding of Cretaceous stratigraphy in both areas.

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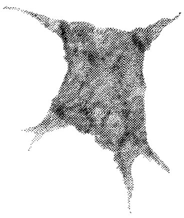


Figure 1.
Wetzeliella ? neocomica Gocht (x315) from 774 ft. in Mandurah No. 1 Bore, South Perth Formation (lower part). Lower Cretaceous (Neocomian).

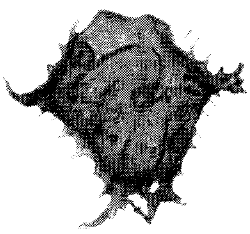


Figure 2.
Wetzeliella ? neocomica Gocht (x400) from the same level in Mandurah No. 1 as Figure 1, but showing apical pylome.

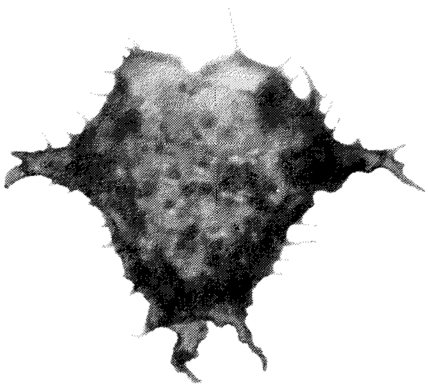


Figure 3.
Wetzeliella ? neocomica Gocht (x525) from the same level in Mandurah No. 1 showing spinose exterior, antapical horns and lateral processes as well as the internal cyst.

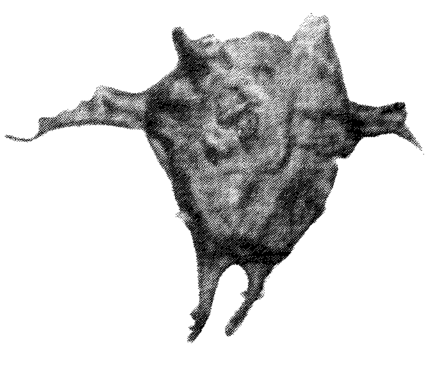
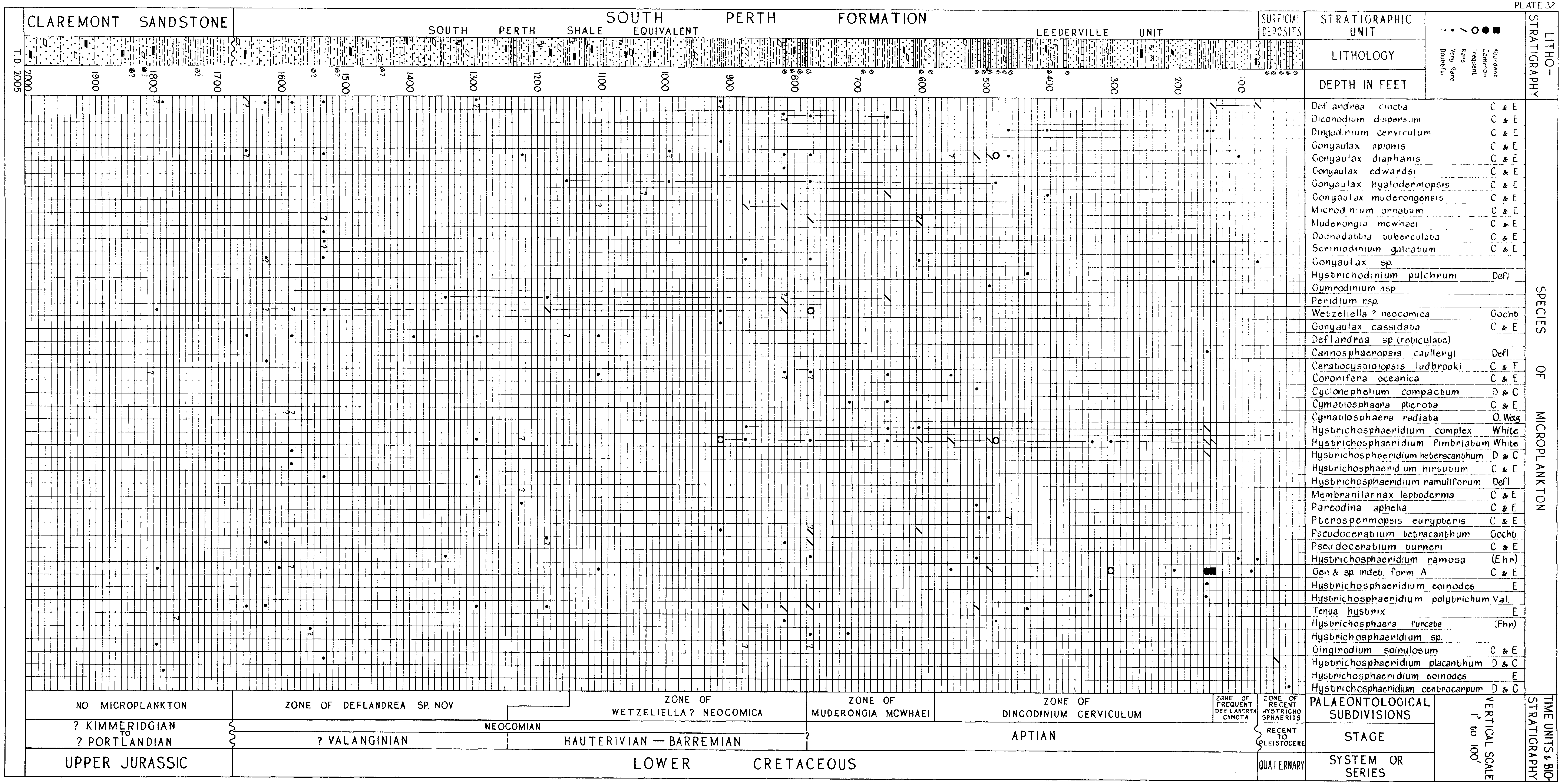


Figure 4.
Muderongia mcwhaei Cookson & Eisenack (x525) from 774 ft. in Mandurah No. 1 Bore with twin antapical horns, vague girdle and apical opening.

Figure 5.
Pseudoceratium tetracanthum Gocht (x600) probable synonym of *Muderongia mcwhaei* Cookson & Eisenack, from the top of the lower part of the South Perth Formation, Mandurah No. 1 Bore.

PHOTOGRAPHS SHOWING MICROPLANKTON FROM THE CRETACEOUS OF THE PERTH BASIN



G.S.W.A

MANDURAH No 1 WATER BORE

MICROPLANKTON DISTRIBUTION CHART

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TRIASSIC AMMONITE IMPRESSIONS FROM THE TYPE SECTION OF THE MINCHIN SILTSTONE, PERTH BASIN

By H. S. Edgell

ABSTRACT

Ammonite impressions from the type section of the Minchin Siltstone, in the Northampton district, include at least three distinct Lower Triassic genera. Predominant amongst these is *Owenites* and other forms resembling the *O. egrediens* assemblage of Timor. This is the first record of Triassic megafossils from surface outcrops in the Perth Basin. The Minchin Siltstone, previously considered as Lower Jurassic, is shown to be the Lower Triassic Kockatea Shale.

INTRODUCTION

Abundant external casts of ammonites on the weathered surfaces of large slabs of ferruginized, white siltstone were collected by Dr. P. E. Playford and Mr. G. H. Low in September, 1962, from the type section of the Minchin Siltstone. This formation has not previously yielded diagnostic fossils and its age has consequently been uncertain. On the basis of stratigraphic position and lithology these siltstones were considered as part of the Chapman Group and were therefore placed within the Lower Jurassic (defined by Johnstone and Playford, *in* McWhae and others, 1958). The present identification of an assemblage of Triassic ammonites, showing strong affinities with those from the Lower Triassic of Timor show that the Minchin Siltstone is in reality of Triassic age. Its type section thus represents previously unrecognised outcrops of the well known Kockatea Shale and the term Minchin Siltstone should be suppressed.

MATERIAL

The specimens submitted for identification consisted of approximately 23 slabs of white to grey siltstone with dark-brown, ferruginized surfaces crowded with external casts of ammonites. Shape and size of the shell, as well as details of coiling and the pattern of ribbing could be discerned from these impressions and it was apparent that at least three genera are represented.

LOCALITY

The material examined comes from Sugarloaf Hill in the Northampton district, W.A., immediately adjacent to the mesa-like hill of Mt. Minchin, where the type section of the Minchin Siltstone was originally defined. The geographic coordinates of this locality are approximately 114°30′ E. Longitude and 28°16′ S. Latitude.

PALAEONTOLOGY

Mode of Preservation

The ammonite impressions on the bedding plane surfaces of the above slabs are only external casts of numerous ammonite tests which have been leached away. Most of the specimens are of soft, finely bedded, white to purplish, micaceous siltstone, the upper surfaces of which have been ferruginized. Casts of the ammonites are preserved by virtue of this surface ferruginization, all calcareous material having been removed by weathering. In general, the state of preservation is poor, so that only the general outline of the shell and the nature of ribbing can be observed.

Description

At least three, and possibly four ammonite genera are represented in the ferruginized external casts collected from the Minchin Siltstone. Unfortunately none of the original, calcareous, shell material is preserved and there are virtually no traces of the suture patterns by which the genera are usually distinguished.

Nevertheless, by observing the nature of the ornament, outline of the shell and its dimensional characteristics, it is possible to distinguish three form groups and to suggest their generic affinities. The three major morphological groups observed are described as follows.

Form Group A: (aff. *Owenites* sp.) see Plate 33, fig. 4. Specimens belonging to this group occur most frequently on the fossiliferous surfaces and comprise eleven of the sixteen, better preserved ammonite casts.

Shell small, involute, oxycone, compressed laterally with arched sides and narrow umbilicus. Outline angust-umbilicate. Peripheral margin or venter simple, rounded, somewhat compressed, appears to lack any distinct keel. Surface nearly smooth. Suture ceratitic with broad, rounded saddles and indeterminately serrated lobes.

The height of the last whorl is approximately one-third the diameter of the shell, while the width is more than one half of the height. The umbilicus is characteristically narrow, about one-fifth of the shell diameter and similarly deep.

Average dimensions of the specimens examined are:—

Maximum shell diameter:	31 mm.
Minimum shell diameter:	25 mm.
Height of last whorl:	11 mm.
Maximum shell thickness (uncertain):	ca. 8 mm.
Diameter of umbilicus:	6 mm.

Form Group B: (aff. *Protychoides* sp.) see Plate 33, figs. 1 and 2. This group includes several incomplete casts of a large ammonite of which the ornament is well preserved and the outline can be reconstructed.

Shell large, discoidal, involute, platycone with flattened sides and rounded venter. Surface subcostate bearing numerous fine radial ribs numbering about 10 per cm. at mid height of whorl. Ribs slightly fasciculate, and apparently dying out towards the venter. Umbilicus wide, shallow with umbilical shoulders broadly rounded. Width of umbilicus slightly less than one quarter of the entire diameter of the shell. Height of the whorl twice its breadth and nearly half the entire diameter with greatest breadth of whorl half way between base and venter. Dimensional characteristics are:—

Maximum shell diameter:	88 mm.
Minimum shell diameter:	75 mm.
Height of last whorl:	40 mm.
Maximum shell thickness:	18 mm.
Diameter of umbilicus:	19 mm.

Form Group C: (aff. *Kashmirites* sp.) see Plate 33 fig 3. A number of specimens with prominent radial ribbing occur in the material collected. These probably include more than one genus but the present collection is inadequate to distinguish them.

Shell small, subdiscoidal, involute with arched venter, whorl section apparently subquadrate with flattened sides. Umbilicus wide (about one quarter of shell diameter) and deep with umbilical shoulders sharply rounded. Height of the whorl less than half its breadth.

Surface ornamented with broad, radial costae numbering up to 40 per whorl. Costae simple, unbranched and somewhat forwardly directed near the venter, extending from umbilical shoulder to venter but more strongly marked ventrally.

Height of whorl approximately one-third greater than its breadth.

Dimensions averaged from the specimens examined are:—

Maximum shell diameter:	44 mm.
Minimum shell diameter:	36 mm.
Height of the last whorl:	16 mm.
Maximum shell thickness:	ca. 10 mm.
Diameter of umbilicus:	11 mm.

Generic Affinities

The numerous small, smooth-shelled involute ammonites of Form A show close affinities with the genus *Owenites* and from point of view of dimensions and external morphology closely resemble the species *Owenites egrediens* from the Lower Triassic (Owenitan) of Timor. In the absence of a full suture pattern, however, this is not a firm identification, as other genera such as *Koninckites* and *Isculitoides* are similar in many respects.

Form B is a large compressed ammonite with a surface bearing many fine, radial ribs which tend to become fasciculate. It reminds one immediately of *Meekoceras*, but lacks the flattened venter characteristic of that genus. In coiling, ribbing and size it appears to belong to the genus *Proptychoides*, particularly *Proptychoides artharberi* (Welter), which is also found in the Lower Triassic of Timor, together with *Owenites egrediens*. Another form which externally resembles Form B is the very variable species *Anasibirites multiformis* Welter, which is, however, generally more prominently ribbed.

It is more difficult to suggest generic affinities for the external casts referred to Form C. These represent an ammonite which is clearly involute with numerous prominent radial ribs and a subquadrate whorl section. A possibly similar form occurring in the Beagle Ridge (B.M.R. No. 10) Bore has been referred to the ammonite cf. *Subinyoites* by Dickens (1961). Although similar in degree of coiling this genus has fewer ribs, more acute venter and is larger than our specimens. The nearest affinities I can suggest are with *Kashmirites* which is generally too evolute and too coarsely ribbed, with the possible exception of *K. densistriatus* Welter.

Correlation

There is a clear indication that the ammonites are of Early Triassic age as was originally suggested by Dr. Playford. Apart from being the first discovery in the Perth Basin of outcropping marine Triassic with megafossils, it also has an important bearing on the age of the Minchin Siltstone. This stratigraphic unit was previously assigned to the Lower Jurassic within the Chapman Group (Johnstone and Playford, 1958) and it now appears that at least part of the Chapman Group (Arkell and Playford, 1954) is Lower Triassic. At least from point of view of age the Minchin Siltstone should be grouped more properly with the well known, Lower Triassic Kockatea Shale. Confirmation of this view has come from the finding in late 1962 of identical ammonite casts discovered by W.A.P.E.T. geologists in similar ferrugined siltstones from the type section of the Kockatea Shale, (pers. comm., specimen in G.S.W.A. Fossil Collection).

Ammonite subdivisions of the Lower Triassic are quite narrowly defined, there being at least fourteen recognisable zones. As a result, determination of genera alone will often suffice to indicate stratigraphic position within the Lower Triassic. Although identifications based on ferruginised external casts are open to considerable doubt, the association of aff. *Owenites* sp., aff. *Proptychoides* sp. and aff. *Kashmirites* sp. suggests the Owenitan substage and the *Owenites* zone. These subdivisions are within the middle part of the Lower Triassic. The specimens from the Minchin Siltstone bear a close resemblance to the *Owenites egrediens* assemblage of Timor (Welter 1922) rather than to the Lower Scythian *Ophiceras-Otoceras* (an *Subinyoites)* fauna of the Himalayas.

CONCLUSIONS

Ferrugined external casts of ammonites from the type section of the Minchin Siltstone, near Northampton, have been examined and divided into three morphological groups. These are provisionally identified as aff. *Owenites* sp., aff. *Proptychoides* sp. and aff. *Kashmirites* sp. Amongst these genera the closest resemblances to our specimens are shown by *Owenites egrediens, Proptychoides artharberi* and *Kashmirites densistriatus* all of which occur together in the middle part of the Lower Triassic in Timor. Similar ammonite casts have also been collected by W.A.P.E.T. geologists from the type section of the Kockatea Shale. Thus, the Early Jurassic age of the Minchin Siltstone will need to be revised to Early Triassic. There is no doubt that the Kockatea Shale and the Minchin Siltstone are one and the same formation, in which case the former has precedence.

The provisional nature of these identifications based solely on partially preserved, external morphology cannot be overemphasised. However, the general aspect of the ammonite assemblage indicates Lower Triassic, while the association of forms suggests the Owenitan substage.

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Figure 2.
aff. *Protychoides* sp. x1

Figure 1.
aff. *Protychoides* sp. (cf. *P. artharberi* (Welter)) x1.

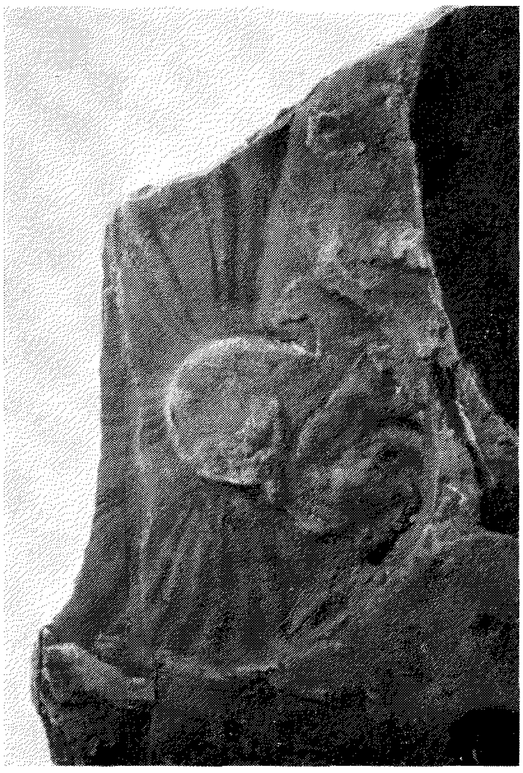

Figure 3.
aff. *Kashmirites* sp. x2.

Figure 4.
aff. *Owenites* sp. (cf. *O. egrediens* Welter) x1.

PHOTOGRAPHS SHOWING TRIASSIC AMMONITE IMPRESSIONS FROM THE TYPE SECTION OF THE MINCHIN SILTSTONE, PERTH BASIN

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THE OCCURRENCE OF UPPER CRETACEOUS MARINE STRATA OF CAMPANIAN AGE AT LANCELIN, PERTH BASIN

By H. S. Edgell

ABSTRACT

In a water bore recently drilled at Lancelin, on the coast about 70 miles north of Perth, a grey marl formation has been encountered beneath Quaternary sands at depths between 105 feet and 150 feet. This lithological unit contains a rich microfauna, with many index species of Foraminifera indicating that it is Upper Cretaceous and of Campanian age. On foraminiferal evidence the formation is thus younger than any previously dated, stratigraphic units in the Cretaceous sequence of the Perth Basin. It represents a new formation definitely younger than the Gingin Chalk and of different lithology from the reportedly unfossiliferous Poison Hill Greensand. The term, Lancelin Beds, is proposed for these marls.

LOCATION

The bore in which these beds have been encountered is known as G.S.W.A. Lancelin 2B and was drilled by the Boomerang Boring Company using a percussion rig, under contract to the Mines Department for Public Works Department. This drilling is being carried out as part of a programme supervised by the Geological Survey of Western Australia to find a town water supply for Lancelin. The borehole is located 70 chains east of the township of Lancelin, which is a small settlement in the Moore River district, on the coast opposite Lancelin Island and approximately 72 miles N.N.E. of Perth.

STRATIGRAPHIC SEQUENCE

In Lancelin 2B Bore the sequence of strata penetrated to the total depth of 150 feet consisted of approximately 105 feet of loosely consolidated, white, Quaternary sands unconformably resting on at least 45 feet of Upper Cretaceous grey marls. The possibility that the lower marls might be of Cretaceous age was immediately seen by the project geologist, Mr. K. H. Morgan, who recognised the abundant fragments of thick, prismatic shell as belonging to the pelecypod genus *Inoceramus*.

The overlying, loosely consolidated, whitish sands can be safely assigned to the Quaternary, as they contain a present-day type of foraminiferal assemblage. This includes ***Elphidium crispum*** (Linnaeus), ***Elphidium macellum*** (Fitchtel & Moll), *Calcarina calcar* d'Orbigny and *Cymbaloboretta squammosa* (d'Orbigny). An association of these species indicates littoral or shallow, near-shore, depositional conditions.

Only 45 feet of the underlying, Upper Cretaceous marls were drilled as they represent "basement" for shallow, water prospects in the Lancelin area. The marl sequence is slightly darker and more glauconitic in the upper 5 feet, but the majority of the stratigraphic unit (as penetrated), consists of typical, soft, light-grey marls with frequent fragments of ***Inoceramus*** shell. An exact age for this Upper Cretaceous formation can be ascertained from its rich foraminiferal fauna, so that it is known to be younger than the Gingin Chalk, which is the youngest, well-dated Cretaceous unit previously known in the Perth Basin. The exact stratigraphic relationships of the grey marls in G.S.W.A. Lancelin 2B, including their thickness, are, as yet, undetermined.

FORAMINIFERAL FAUNA

Abundant Foraminifera occur at all levels in the grey marls between 105 feet and 150 feet in Lancelin 2B. These include a great diversity of species amongst which the most common are thin shelled, planktonic forms belonging to the Globigerinidae, Globorotaliidae and Heterohelicidae. Calcareous, benthonic species belonging to the families Lagenidae and Anomalinidae are also frequent, but benthonic forms with arenaceous, or agglutinated tests are very rare. The total aspect of the foraminiferal assemblage, together with the frequent occurrence of Inoceramus fragments, indicates deposition under fully marine conditions in the inner neritic zone.

The species of planktonic Foraminifera, which have been identified in a composite sample representing the interval 110 feet to 150 feet in Lancelin 2B, are given in the following list.

Planktonic Foraminifera

(Depth: 110 ft. to 150 ft.)

- *Globigerina cretacea* d'Orbigny (r)
- ***Globigerinella aspera*** (Ehrenberg) (c)
- *Globotruncana globigerinoides* Brotzen (f)
- *Globotruncana arca* (Cushman) (r)
- *Globotruncana mariai* Gandolfi (c)
- *Globotruncana ventricosa* White (c)
- *Gümbelina globulosa* (Ehrenberg) (c)
- *Gümbelina planata* (Cushman) (f)
- *Pseudogümbelina striata* (Ehrenberg) (r)
- *Rugoglobigerina* cf. *rugosa* (Plummer) (r)

All these planktonic species are typical of Upper Cretaceous strata in many parts of the world. In addition the species *Globotruncana mariai, Glt. ventricosa, and Pseudogümbelina striata* are found only in the Upper Senonian.

Benthonic Foraminifera

(Depth: 110 ft. to 150 ft.)

- *Anomalina rubiginosa* Cushman (f)
- *Bolivinitella eleyi* (Cushman) (vr)
- *Bolivinoides granulatus* Hofker (r)
- ***Dentalina basiplanata*** Cushman (r to f)
- *Dentalina catenula* Reuss (r to f)
- *Cibicides excavata* Brotzen (f)
- *Dorothia biformis* Finlay (vr)
- *Dorothia bulletta* (Carsey) (r)
- *Ellipsoidella* cf. *solida* (Brotzen) (r)
- *Eouvigerina americana* Cushman (r)
- *Frondicularia mucronata* Reuss (vr)
- *Frondicularia teuria* Finlay (vr)
- *Guttulina hantkeni* Cushman & Ozawa (vr)
- *Gyroidina nitida* Reuss (f)
- *Lagena amphora* Reuss var. *paucicosta* Franke (r)
- *Lagena hexagona* (Williamson) (vr to r)
- *Lagena sulcata* (Walker & Jacob) (vr)
- *Marginulina* cf. *curvisepta* Cushman & Goudkoff (f)
- *Marginulina decursecostata* Thalmann (r)
- *Marginulina* cf. *trinitatensis* Cushman (r to f)
- *Marssonella oxycona* Reuss (r)
- *Massilina* cf. *ginginensis* Chapman (r)
- *Neoflabellina praereticulata* Hiltermann (vr)
- *Nodosaria prismatica* Reuss (r)
- *Planularia* sp. aff. *liebusi* Brotzen (vr)
- *Planulina rakauroana* Finlay (f to c)
- *Praebulimina ovulum* (Reuss) (vr)
- *Pullenia cretacea* Cushman (r)
- *Robulus macrodiscus* (Reuss) (vr)
- *Robulus* spp. (f)
- *Spiroplectammina gryzybowskii* Frizzell (f)
- *Stensiöina* sp. nov. (f)
- *Valvulineria allomorphinoides* Reuss (vr)
- *Verneuilina parri* Cushman (r)

The benthonic Foraminifera listed above are only part of a much more extensive assemblage of species, which could be identified by more detailed study. However, they represent the more frequent and important of the species of foraminiferal benthos. Included amongst them are species which are known to have very restricted stratigraphic ranges, such as *Bolivinoides granulatus* Hofker and *Neoflabellina praereticulata* Hiltermann.

MICROPLANKTON CONTENT

The term "microplankton", as conventionally applied, refers to the protistids with acid-insoluble shells, particularly the dinoflagellates and hystrichosphaerids. Certain ambiguity exists, however, as microscopic planktonic organisms belonging to the Foraminifera and Radiolara are also microplankton in the wide sense. The main difference is that tests of the dinoflagellates and hystrichosphaerids are generally from one tenth to one fifth the size of those of the Foraminifera and Radiolaria, as well as being insoluble in hydrofluoric acid.

Palynological preparations of the marl material from depths between 110 feet and 115 feet in G.S.W.A. Lancelin 2B have yielded residues very rich in these smaller acid-insoluble organisms or "microplankton". They include a great variety of dinoflagellates and hystrichosphaerids, many species of which are known to be restricted stratigraphically to certain parts of the Upper Cretaceous. A brief list of some of the microplankton identified is given below, although many new species not recorded here, appear in the residue.

Dinoflagellata

(Depth: 110 ft. to 115 ft.)

- *Deflandrea cretacea* Cookson (r)
- *Deflandrea echinoidea* Cookson & Eisenack (r)
- *Diconodinium multispinum* (Defl. & Cookson) (vr)
- *Diconodinium* sp. aff. *spinosissima* (Defl.) (vr)
- *Ginginodinium* sp. aff. *spinulosum* Cookson & Eisenack (vr)
- *Gonyaulax margaritifera* Cookson & Eisenack (r)
- *Gymodinium westralium* Cookson & Eisenack (f)
- *Nelsoniella aceras* Cookson & Eisenack (vr)
- *Odontochitina porifera* Cookson (vr)

Hystrichosphaeridea

(Depth: 110 ft. to 115 ft.)

- *Aiora* cf. *fenestrata* (Cookson & Eisenack) (vr)
- *Hystrichosphaera furcata* (Ehrenberg) (c)
- *Hystrichosphaeridium complex* (White) (r)
- *Hystrichosphaeridium eoinodes* Eisenack (vr)
- *Hystrichosphaeridium heteracanthum* Defl. & Cookson (f)
- *Hystrichosphaeridium* cf. *isocalamus* Defl. & Cookson (vr)
- *Hystrichosphaeridium ramuliferum* Deflandre (c)
- *Pterospermopsis australiensis* Defl. & Cookson (vr)

Amongst the "microplankton" species listed above, those belonging to the Dinoflagellata are particularly useful from a stratigraphic viewpoint. Thus, all the definitely-identified dinoflagellate species listed above are restricted to the Senonian, and for the most part the Upper Senonian (or Campanian-Santonian). In their studies of microplankton from the Upper Cretaceous of the Carnarvon Basin, Cookson and Eisenack (1958, 1960) find these dinoflagellate species mainly in the Korojon Calcarenite and Toolonga Calcilutite.

The species belonging to the Hystrichosphaeridea appear to be less restricted stratigraphically. Although this hystrichosphaerid faunule suggests a Late Cretaceous age it does not indicate any particular stage, as is the case with the dinoflagellate species.

MICROFLORA

The aspect of the microflora obtained from a sample of the grey marl taken at 110 feet to 115 feet in Lancelin 2B is most interesting. This is because spores and pollen grains, through the interval Lower Cretaceous to Middle Devonian, have been previously described from Western Australia, but no account has been given of those from the Upper Cretaceous. As would be expected from a fully marine sediment, spores and pollen grains are not abundant in the palynological residue and microplankton predominate. The most common species of microspore is *Gleicheniidites circinidites* (Cookson), closely allied to the modern genus *Gleichenia*. It is this, so-called *"Gleichenia Assemblage"* which predominates in the West Australian Upper Cretaceous, as opposed to the *Microcachrydites* Assemblage in the Lower Cretaceous. Some of the spores and pollen grains identified as referable to known taxa are given in the following list.

Spores

(Depth: 110 ft. to 115 ft.)

- ?*Appendicisporites* sp. (vr)
- *Cingulatisporites* sp. aff. *valdensis* Couper (vr)
- *Gleicheniidites circinidites* (Cookson) (f)
- *Microreticulatisporites scrobiculatus* Ross (r)
- *Trilobozonosporites rotalis* (Weyland & Krieger) (vr)

Pollen Grains

(Depth: 110 ft. to 115 ft.)

- cf. *Araucariacites australis* Cookson (r)
- *Inaperturopollenites emmaensis* Mürr & Pflug (f)
- *Pityosporites* cf. *microalatus* (R. Potonie) (r)
- *Tricolpites pachexinus* Couper (vr)
- cf. *Vacuopollis semiconcavus* Pflug (vr)

The occurrence of *Trilobozonosporites rotalis* in this microfloral assemblage is significant as this genus has not been recorded previously in Australia and is known from the European Senonian. Amongst described Upper Cretaceous microfloras, the most similar which can be found are those from the Aachener Kreide (Middle Senonian of West Germany described by Weyland & Krieger, 1953) and from the Haumurian Stage of the New Zealand Upper Cretaceous (Couper, 1953, 1960).

CORRELATION

The time-stratigraphic and litho-stratigraphic correlation of these grey marls between 105 feet and 150 feet in the G.S.W.A. Lancelin 2B Bore show they constitute a new formation younger than others previously known in the Perth Basin.

Foraminiferal Evidence

Foraminiferal index species, such as *Bolivinoides granulatus* Hofker and *Neoflabellina praereticulata* Hiltermann, which are known to be restricted to the Campanian in Europe, Asia and North America, provide most precise evidence of the age of the marls in G.S.W.A. Lancelin 2B. In north-western Europe, where most detailed studies have been made of the stratigraphic ranges of these species, it has been found that they are both limited to the Upper Campanian. According to Belford (1960), *Neoflabellina praereticulata* occurs as low as basal Campanian in the Carnarvon Basin. It is, however, restricted to strata of definite Campanian age in that area, such as the Toolonga Calcilutite in the Murchison River and Shark Bay areas, and the lower Korojon Calcarenite in the Giralia-Cardabia area. A species very similar to *Bolivinoides granulatus*, referred by Edgell (1954) to *B. decorata* cf. *delicatula*, also occurs in Campanian strata at depths of 935 feet to 995 feet in the Brickhouse Bore, near Carnarvon.

Planktonic species of Foraminifera with narrow time ranges, also occur in the marls encountered in the G.S.W.A. Lancelin 2B Bore. These include *Globotruncana mariai* Gandolfi, *Glt. ventricosa* White, *Glt. globigerinoides* Brotzen and *Pseudogümbelina striata* (Ehrenberg). The first of these species is known to be restricted to the Campanian in the Upper Cretaceous type sequence of the Paris Basin. The remaining three species occur in the Toolonga Calcilutite of the Carnarvon Basin and are also restricted to Campanian elsewhere, with the exception of *Globotruncana ventricosa* the range of which is Campanian to Santonian.

There is, thus, clear foraminiferal evidence from both planktonic and benthonic index species to indicate that the marls encountered in G.S.W.A. Lancelin no. 2B are of Campanian age.

Microplankton Correlation

Amongst the species of acid-insoluble microplankton identified from a depth of 110 ft. to 115 ft. in Lancelin 2B Bore several of those belonging to the Dinoflagellata have restricted stratigraphic ranges. These are:—

Deflandrea echinoidea Cookson and Eisenack from the Toolonga Calcilutite (Campanian-Santonian), Rough Range South No. 1 Bore, Core 56, 2,390 ft. - 2,393 ft. and core 59 (2,435 ft. 2,447 ft.).

Gonyaulax margaratifera Cookson and Eisenack from the same formation, age, bore and cores as the above.

Gymnodinium westralium Cookson & Eisenack from the Toolonga Calcilutite and upper Gearle Siltstone (Campanian-Santonian), Rough Range South No. 1 Bore, cores 56-63; Brickhouse Bore, between 535 ft and 715 ft. (Campanian).

Nelsoniella aceras Cookson & Eisenack from the Toolonga Calcilutite, Rough Range South No. 1 Bore, Cores 56, 58-59 (2,390 ft. -2,447 ft.) (Campanian-Santonian).

Odontochitina porifera Cookson from the upper Gearle Siltstone, Rough Range South No. 1 Bore, core 62, 2,505 ft.-2,511 ft. and the Toolonga Calcilutite, same bore, cores 56-59, 2,390 ft.-2,429 ft. (Campanian-Santonian).

Occurrence of these dinoflagellate species in Upper Cretaceous of the Carnarvon Basin appears to be limited to strata of Campanian to Santonian age. Although their indication of the age of marls in the Lancelin bore are not as precise as that given by Foraminifera, they provide evidence of a correlation with the Upper to Middle Senonian strata encountered in the Rough Range South No. 1 Bore.

Microfloral Evidence

The assemblage of spores and pollen grains identified from the grey marls drilled in G.S.W.A. Lancelin 2B Bore are of definite Upper Cretaceous aspect. This is shown by the predominance of *Gleicheniidites circinidites* (Cookson). The occurrence of many species of spores and pollen grains, not previously encountered in the Gingin Chalk, Molecap Greensand or Osborne Formation, indicates that the Lancelin marls are younger. This is further supported by the finding of *Trilobozonosporites rotalis* (Weylands & Krieger) and other spores and pollen species common in the Middle Senonian Archener Kreide of north-western Germany. At the present state of knowledge of Late Cretaceous microfloral assemblages in Australia, an exact correlation is not possible. The much less frequent occurrence of angiosperm pollen types in the Late Cretaceous of Western Australia, as compared with the Northern Hemisphere, is a striking feature attributable to endemic floral provinces.

Lithological Correlation

The distinctive lithological nature of the soft, light grey marls encountered between the depths of 105 feet and 150 feet in G.S.W.A. Lancelin 2B Bore, indicate that they form a new lithostratigraphic unit, not formerly recognised in the Perth Basin. There is a marked uniformity in lithology between these depths and the unit is one of homogeneous lithology, although its exact thickness has yet to be established by further shallow drilling.

Lithologically the grey marls in G.S.W.A. Lancelin 2B, bear a close resemblance to the Toolonga Calcilutite, which consists predominantly of pale-green to pale-grey calcilutite. It is significant, too, that the latter formation has its type area in the extreme south of the Carnarvon Basin, on Murchison House Station and is recognisable in the subsurface as far north as the Exmouth Gulf area. The wide distribution of the Toolonga Calcilutite, and similarity of lithology and microfauna, make it conceivable that the formation extends southward in the offshore area and overlaps the seaward margin of the Perth Basin in the Lancelin area. However, the occurrence at Lancelin is some 225 miles south of the nearest known outcrop of Toolonga Calcilutite and it is thus thought best to distinguish these Lancelin marls as a separate formation.

In the Brickhouse Bore, near Carnarvon, a closely similar lithology, consisting of light-grey marl with *Inoceramus* fragments, was encountered between the depths of 320 feet and 875 feet. These strata were examined in detail by the writer and contained an identical foraminiferal assemblage of Campanian age. Similar light-grey marls were also found conformably underlying the Korojon Calcarenite at the top of the Gearle Siltstone in the C.Y. Creek section of the Giralia Anticline. This lithological occurrence, although similar to that at Lancelin, is somewhat older, being of Santonian age and thus equivalent to the lower part of the Toolonga Calcilutite.

There is no known rock-stratigraphic unit of comparable lithology to the Lancelin marls in the Upper Cretaceous of the Perth Basin. The Osborne Formation consists of black, glauconitic, sandy claystone, is not sufficiently calcareous to be termed a marl, and is considerably older than the formation at Lancelin. Also excluded from comparison are, the Molecap Greensand, which is predominantly a greensand and glauconitic sandstone, and the Gingin Chalk, which is a typical, white, fossiliferous chalk or calcarenite. Both the latter formations are of established Santonian age and thus slightly older than the Lancelin marls.

The Poison Hill Greensand is also of completely different lithology to the marls at Lancelin. It consists primarily of glauconitic sandstone and greensand and is reportedly unfossiliferous. It is regarded as Campanian in age (Teichert 1947) mainly on the basis of superposition and may therefore be an age equivalent of the fossiliferous grey marls encountered in G.S.W.A. Lancelin 2B. Belford (1958) has stated that "lithologically, the Poison Hill Greensand may be compared with the Boongerooda Greensand of the Carnarvon Basin; this formation is regarded as Paleocene in age." The inference that the Poison Hill Greensand is of Paleocene age seems unlikely to prove correct, but it is clear that the Campanian age of the formation has not yet been established by fossil evidence.

CONCLUSIONS

Micropalaeontological and palynological examination of samples from the G.S.W.A. Lancelin 2B Bore have yielded information on the ages, formations and facies of the strata penetrated. In particular, evidence is provided of a new Upper Cretaceous formation in the Perth basin, of different lithology and younger, than any previously dated by fossil evidence. This formation was encountered between the depths of 105 feet and 150 feet and consists of light-grey, fossiliferous marls of marine, neritic facies. The name Lancelin Beds is given for this new lithostratigraphic unit. Further shallow drilling is necessary to determine its total thickness and detailed lithological succession. Loosely consolidated, white, calcareous sands of Quaternary age unconformably overlie the marls at Lancelin and are regarded as superficial deposits.

A stratigraphic summary of the sequence encountered in the G.S.W.A. Lancelin 2B Bore is shown in the following table:—

TABLE 1.—STRATIGRAPHIC SEQUENCE IN G.S.W.A. LANCELIN 2B WATER BORE.

SERIES	STAGE	FORAMINIFERAL ASSEMBLAGE	DEPTH INTERVAL	FACIES	FORMATION
Recent to Pleistocene	....	*Elphidium crispum* Assemblage	0 ft. to 105 ft.	Marine, littoral	Superficial deposits
Unconformity					
Upper Cretaceous	Campanian	*Globotruncana mariai* Assemblage	105 ft. to T.D.150 ft.	Marine, inner neritic	"Lancelin Beds"

Identification of species of Foraminifera, Dinoflagellata, spores and pollen grains all indicate a clear Senonian age for the grey marls between 105 feet and 150 feet in G.S.W.A. Lancelin 2B. In addition, the occurrence of foraminiferal index species in these marls gives a more exact age indication, as Campanian, and suggests the Upper Campanian.

Previously, the youngest Late Cretaceous formation for which an age was definitely established was the Gingin Chalk of Santonian age. The overlying Poison Hill Greensand is unfossiliferous in outcrop although it is generally referred to the Campanian Stage. It is possible that the Lancelin Beds are the age equivalent of the Poison Hill Greensand, but they are of different lithology, very fossiliferous and of established age.

A table summarising the correlation of the Lancelin Beds with other Late Cretaceous formations in the Carnarvon and Perth Basins, is given below.

TABLE 2. CORRELATION OF UPPER CRETACEOUS FORMATIONS IN THE CARNARVON AND PERTH BASIN AND POSITION OF THE "LANCELIN MARL"

SERIES	STAGE	CARNARVON BASIN: EXMOUTH GULF AREA	CARNARVON BASIN: MURCHISON RIVER DISTRICT	PERTH BASIN: LANCELIN AREA	PERTH BASIN: GINGIN DISTRICT
Upper Cretaceous	Maestrichtian	Miria Marl			
	Campanian	Korojon Calcarenite	Toolonga Calcilutite	Lancelin Beds ?	? Poison Hill Greensand
	Santonian	Toolonga Calcilutite	Alinga Greensand	(Lower section not drilled)	Gingin Chalk
	Coniacian				Molecap Greensand
	Turonian	Upper Gearle Siltstone			
	Cenomanian	Lower Gearle Siltstone			Osborne Formation

It is significant that a new and younger stratigraphic unit of the Upper Cretaceous of the Perth Basin has been encountered in boring for water at Lancelin. Previously it could only be surmised that Jurassic or Cretaceous rocks underlay the Coastal Limestone in this area. This extends our knowledge of the Cretaceous formations in the Perth Basin, while the study of associated assemblages of Foraminifera, microplankton and microflora provides useful information for the dating of other Cretaceous sequences.

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Geological Survey Section Index

DIVISION V

School of Mines, Western Australia Annual Report—1963

The Under Secretary for Mines

I have the honour to submit for the information of the Honourable the Minister for Mines my report for the year 1963. The report refers to Kalgoorlie and to Norseman, and this year the tables for both Schools have been collected together at the end of the report instead of being distributed through each section.

KALGOORLIE

Enrolments

The number of students enrolled in 1963 was 365—an increase of 13 by comparison with the previous year.

Table I gives the individual and class enrolments for 1963 and for the four previous years; Table II, the enrolments in the various subjects; and Table III, the students enrolled for the various courses. The figures indicate quite an increase in number of students enrolled for Certificate Courses—particularly the Draughtsman's Certificate. With the steady increase in standard required for the Associateship Courses and re-organisation of the Certificate Courses this is to be expected and it would seem likely that in the future there will be an increasing number of students completing Certificate Courses and not going on to Associateship Courses. The number enrolled for Associateship Courses this year is about the same as in 1962.

Revenue

The revenue for the year was £6,940 15s., which amount includes £1,000 for the Apparatus and Equipment Trust Fund as part of the 1962 Contribution. Table IV shows how the revenue was made up and Table V the fees paid by students of the various age groups. The increase in the numbers of students noted in last year's Report continued in 1963.

Staff

The following Staff changes occurred during the year:—

Beardman, B. W., Junior Clerk, 4/11/63—Appointed.

Budrey, D. B., Messenger, 27/9/63—Resigned.

Gard, L. K., Typist, 15/1/63—Appointed.

Hewett, G. R., Typist, 29/11/63—Resigned.

Hollett, J., Junior Clerk, 5/11/63—Transferred.

Jacobs, H. R., Typist, 18/1/63—Resigned.

Rowe, E. J., Typist, 9/12/63—Appointed.

Rucklidge, M. M. P., Librarian, 22/4/63—Appointed.

Rucklidge, M. M. P., Librarian, 6/9/63—Resigned.

Rucklidge, M. M. P., Librarian, 7/10/63—Appointed.

Rucklidge, M. M. P., Librarian, 29/11/63—Resigned.

Trelevan, R., Messenger, 4/10/63—Appointed.

Wallis, H. W., Cadet, 18/2/63—Appointed.

Wilkinson, E. A., Lecturer, 30/5/63—Resigned.

Courses of Study

The Courses remained very much the same as in 1962. Some changes were made in the Engineering Draughtsman's Certificate Course. The Mine Manager's Certificate Course, which had for some years been the academic qualification for Certificate of Competency in Western Australia, was dropped following a revision of the Mines Regulation Act, and the Mine Manager's Course (Second Class) was introduced. Some changes were also made in the Technician Courses.

Annual and Supplementary Examinations

The results of the Annual Examinations are summarized in Tables VI and VII, which are based on class enrolments and individual enrolments respectively. Generally the figures are similar to those of earlier years, but the percentage of students passing is slightly lower than in the four previous years.

The results for individual subjects are given in Appendix 1.

Scholarships and Prizes

Only one student, L. M. Karczub, held a Mines Department Scholarship. He completed a satisfactory year's work, but as this was the second year the Scholarship had been held it was not available to him for 1964.

Fourteen students held Chamber of Mines Scholarship during 1963. Of these, two failed to complete a satisfactory year's work and their Scholarships were cancelled, two completed the Courses for which they were enrolled, and the remainder had their Scholarships renewed for 1964. Altogether 15 students have now completed Associateship Courses under the Chamber of Mines Scholarship programme.

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

It is interesting to record here that Mr. W. E. Baldwin, who held a Chamber of Mines Scholarship and who completed the Associateship Course in Engineering at the end of 1963, was awarded an A.E.I. Overseas Fellowship and will leave for England early in 1964. Since 1956, six School of Mines Students have been awarded Fellowships.

Diplomas and Certificates

In 1963, seven students completed Associateship Courses; 12, Certificate Courses; and 2, Technician Courses. The numbers are lower than usual. Details are given in Table VIII.

On Wednesday, May 29, the Annual Presentation Night was held in the Kalgoorlie Town Hall. Once again the Minister for Mines, the Honourable A. F. Griffith, presented Diplomas, Certificates and Prizes to the successful students. The Guest Speaker was Mr. L. C. Brodie-Hall, General Superintendent, Western Mining Corporation. After outlining the history of mining, Mr. Brodie-Hall referred to some outstanding performances in recent years and to the need for increased mechanisation, instrumentation, and automation in the future. He referred to the increasing use of geophysical and geo-chemical methods for exploration and outlined how these procedures are used. Mr. Brodie-Hall concluded his address by directing attention to the opportunities for trained men in the industry, to the need for enterprising management, and to the need for co-operation between management and men, which is generally well developed in the gold mining industry in Western Australia.

Mr. R. M. King, President of the Students' Association, thanked the Minister for making the presentations and Mr. Brodie-Hall for his address.

Library

Both at the start of the year and at the end of the year we were without a Librarian and consequently no progress has been made with the development of the Library. It has, in fact, been difficult to continue all arrangements which existed at the end of 1962. It is hoped that this position will change in 1964.

Lists of new books were circulated at somewhat irregular intervals. The Library Bulletin referred to in last year's report was continued.

The number of new books added was 488 and the total number of items catalogued at December 31 was 8,216.

Services to the Public

The School continued to provide the usual services to the public in addition to its teaching activities. The number of samples submitted for assay or mineral determination decreased from 561 in 1962 to 458 in 1963, but was still higher than the number submitted in the three years prior to 1962. The decrease occurred both in the number of samples submitted for gold assay and in the number for mineral determination. Details are given in Table IX.

Buildings

The alterations and additions to the Kalgoorlie Metallurgical Laboratory referred to in last year's report were completed in 1963, including the air conditioning of the balance room. Much better working conditions now exist in the Laboratory, but the buildings are still of a temporary nature and the pilot plant is badly placed. This should be housed in a separate building.

During the year new buildings were commenced for the Department of Mathematics and Physics. These are of brick construction and will provide much needed laboratory and lecture room space. They are the first brick buildings erected at the School since about 1908. The buildings will be ready for use when School re-opens in 1964.

Requirements of the School

Reference was made in the 1961 Annual Report to the need for an overall plan for future buildings. During the year the School was visited by the Principal Assistant, Design (Architectural Division, Public Works Department) and a sketch plan was prepared. The new building for Mathematics and Physics conforms to this plan and sketch plans were also prepared for a building to house the Departments of Engineering and of Mining. This building was still under consideration at the end of the year. This is a very urgent need and a start should be made on this building in 1964.

Other Departments require additional space and the preparation of an overall plan in more detail than the sketch plan already referred to is essential.

Advisory Committee

The Committee met seven times and attendances were as follows: Mr. Kay, 6; Mr. Blown, 6; Mr. Field, 5; Mr. Golding, 5; Mr. Havlin, 1; Mr. Hobson, 7; Mr. Mundle, 4 (possible 6); Mr. Simpson, 1 (possible 1).

In October Mr. Mundle resigned from the Committee because of his retirement from the industry and Mr. R. C. Simpson was appointed by the Chamber as its representative. Mr. Mundle had been a member of the Committee since 1956 and at its October meeting the Committee recorded its appreciation of the help received from Mr. Mundle.

Equipment to the value of £1,282 was approved for purchase.

Kalgoorlie Metallurgical Laboratory

Three reports of investigations and 414 Certificates were issued during the year. As usual many inquiries were answered by the Senior Research Metallurgist and by members of the Laboratory staff. The Senior Research Metallurgist continued as a member of the Chamber of Mines Metallurgical Committee and work was done throughout the year for this Committee. The year's work is summarised in Table X and more details are given in a report by the Senior Research Metallurgist, which appears as Appendix 3.

Students' Association ....

The President of the Association at the start of the year was Mr. R. M. King who, because of the pressure of normal school work, resigned about the middle of the year. He was succeeded by Mr. W. E. Baldwin. The usual functions were held during the year and the Association was quite active.

NORSEMAN

Enrolments

The number of students enrolled was 68—a decrease of one by comparison with 1962. Table I sets out the individual and class enrolments during the year and during the four previous years; Table II, the enrolments in the various classes; and Table III, the enrolments in the various courses. The tables show that the figures are similar to those for earlier years.

Revenue

The revenue received was £175 19s. 6d. and came mainly from class fees.

Staff

There were no changes in full time staff. Five part time lecturers were employed.

Subjects Taught

Eighteen subjects were taught, and as in previous years use was made of mine workshops for practical work. Some of the subjects taught at Norseman were not available in Kalgoorlie and were introduced to meet the special needs of trade students at Norseman.

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 figures are similar to those for previous years and as is frequently so are slightly better than the corresponding figures for Kalgoorlie.

The results for individual subjects are given in Appendix 1.

Scholarships and Prizes

The Reg Dowson Scholarships for 1963 were awarded to H. R. Eyre and to R. J. Murphy. The two students who were awarded Reg Dowson Scholarships at the end of 1962 completed a satisfactory year's work in 1963. No other Scholarships or prizes were awarded to Norseman students.

Buildings

During the year minor repairs were made to the buildings, which are generally in good condition.

Advisory Committee

The Advisory Committee did not meet during the year. Meetings will be resumed in 1964.

ACKNOWLEDGEMENTS

During the year members of the Staff have assisted students in every way and have also answered many questions from parents and from members of the public. The Registrar and office staff in Kalgoorlie and the Registrar in Norseman have provided most of the statistical information for this report.

Assistance and co-operation have been received from Advisory Committees, Mining Companies, Head Office Staff and all sections of Mines Department, other Government Departments, and from the "Kalgoorlie Miner" and the Australian Broadcasting Commission in Kalgoorlie.

R. A. HOBSON,
March 26, 1964. Director, School of Mines.

TABLE I.
Enrolments.
1959-1963.

Year	Kalgoorlie		Norseman	
	Individual	Class	Individual	Class
1959	365	916	55	140
1960	332	967	61	146
1961	310	804	65	139
1962	352	945	69	160
1963	365	926	68	140

TABLE II.
Class Enrolments.
1963.

Subject	Kalgoorlie		Norseman	
	First Term	Second Term	First Term	Second Term
Chemistry P	28	21	....	....
Chemistry Q	36	35	....	....
Chemistry 1	9	9	....	....
Chemistry 2	Not	Available	....	....
Analytical Chemistry 1....	6	4	....	....
Analytical Chemistry 2	3	3	....	....
Chemical Metallurgy 1	3	2	....	....
Chemical Metallurgy 2	Not	Available	....	....
Mineral Dressing 1	14	14	....	....
Mineral Dressing 2	7	7	....	....
Mineral Dressing 3	....	....	....	....
Physical Metallurgy	5	4	....	....
Assaying	13	13	....	....
Metallurgy A	7	7	....	....
Mathematics P	58	41	13	7
Mathematics Q	65	50	11	8
Mathematics 1.1	36	25	5	3
Mathematics 1.2	7	7	....	....
Mathematics 1.2 (Stat)	12	....	....	....
Mathematics 2	13	12	....	....
Physics Q	37	37	9	7
Physics 1.1	35	31	....	....
Physics 1.2	17	15	....	....
Physics 2	10	9	....	....
Electronics	10	8	....	....
Engineering Drawing P	20	13	10	7
Engineering Drawing Q	58	30	9	6
Engineering Drawing 1	24	19	4	3
Engineering Drawing W	5	8	....	....
Engineering Design	Not	Available	....	....
Mechanical Engineering 1	15	15	....	....
Mechanical Engineering 2	4	4	....	....
Electrical Engineering 1	21	19	....	....
Electrical Engineering 2.1	4	4	....	....
Electrical Engineering 2.2	4	3	....	....
Structural Engineering 1	14	13	....	....
Structural Engineering 2.1	8	8	....	....
Structural Engineering 2.2	3	3	....	....
Machine Design 1.1	4	4	....	....
Machine Design 1.2	13	11	....	....
Hydraulics	7	7	....	....
Materials of Construction	18	18	....	....
Workshop Practice 1	13	10	....	....
Workshop Practice A	4	....	1	....
Workshop Practice B	3	....	6	7
Workshop Practice C	5	4	....	....
Workshop Practice D	....	....	....	....
Steam Engine Driving	Not	Available	8	8
Welding A	18	18	14	14
Welding B	10	10	5	5
Electrical Theory	Not	Available	....	....
Internal Combustion Engines	14	14	....	....
Geology Q	27	24	....	....
Geology 1.1	16	13	6	6
Geology 1.2	7	7	....	....
Geology 2.1	9	9	....	....
Geology 2.2	3	3	....	....
Geology 2.3	Not	Available	....	....
Geology 3.1	Not	Available	....	....
Geology 3.3	Not	Available	....	....
Mining 1	14	11	8	8
Mining 2.1	9	9	....	....
Mining 2.2	3	3	....	....
Mining 3	9	8	....	....
Mining 3 (Sect. A)	1	1	....	....
Mining 3 (Sect. B)	3	3	....	....
Mine Ventilation	5	5	5	5
Surveying 1	21	17	....	....
Surveying 2.1	8	8	....	....
Surveying 2.2	9	4	....	....
Mining A	9	6	....	....
English P	....	....	....	....
English Q	19	15	....	....
English 1	19	17	....	....
Leaving English	20	16	....	....
Mathematics A	....	....	....	....
Mathematics B	....	....	8	5
Physics P	....	....	....	....
Electrical Theory A	....	....	....	....
Electrical Theory B	....	....	7	7
Electrical Drawing A	....	....	....	....
Electrical Drawing B	....	....	6	6
Totals	931	763	135	112
Totals, 1962	930	755	155	133

TABLE III.

Numbers of Students Enrolled for Various Courses.

Course	Kalgoorlie					Norseman				
	1959	1960	1961	1962	1963	1959	1960	1961	1962	1963
ASSOCIATESHIP COURSES										
Mining	35	37	24	27	34	....	2	3	6	4
Metallurgy	21	13	17	15	18	....	....	....	....	....
Engineering	43	49	49	44	37	3	2	2	3	....
Mining Geology	13	15	19	11	9	....	....	....	1	....
Total	112	114	109	97	98	3	4	5	10	4
CERTIFICATE COURSES										
Assayer's	5	3	3	6	10	....	....	....	....	....
Mine Surveyor's	23	25	30	27	37	8	10	13	11	9
Mine Manager's	....	....	4	3	....	....	....	....	....	....
Engineering Draughtsman's	9	4	6	8	33	1	2	2	....	8
Electrical Engineering	7	2	2	....	....	....	1	1	1	....
Mechanical Engineering	....	4	1	1	....	....	....	1	....	....
Total	44	38	46	45	80	9	13	17	12	17
TECHNICIAN COURSES										
Engine Operation and Maintenance....	1	2	1	1	....	14	6	17	12	2
Workshop Foreman's	6	7	6	2	....	3	8	3	6	....
Welding	7	10	16	24	17	4	5	4	6	7
Workshop (Mechanical)	....	....	....	....	....	....	....	....	....	12
Workshop (Electrical)	....	....	....	....	2	....	....	....	....	5
Mine Manager's (2nd)	....	....	....	....	5	....	....	....	....	....
Total	14	19	23	27	24	21	19	24	24	26
NO SET COURSE										
Preparatory Subjects	61	47	44	38	27	9	3	3	11	11
Qualifying Subjects	....	....	....	22	17	....	....	....	....	....
External Students	3	6	3	....	....	....	....	....	....	....
Junior and Leaving	2	12	9	28	32	....	....	....	....	....
University	10	7	4	3	1	....	....	....	....	....
Others	119	89	72	92	86	13	22	16	12	10
Total	195	161	132	183	163	22	25	19	23	21
TOTAL FOR YEAR	365	332	310	352	365	55	61	65	69	68

TABLE IV.

Revenue, 1961-1963.

	Kalgoorlie			Norseman		
	1961	1962	1963	1961	1962	1963
	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.
Class Fees	1,232 3 6	1,419 0 0	1,514 4 0	....	....	139 4 6
Registration Fees	79 10 0	97 0 0	82 0 0	....	....	20 0 0
Lecture Notes	56 2 6	62 15 0	64 17 6	....	....	10 15 0
Laboratory Deposits	121 0 0	115 0 0	150 0 0	....	....	....
Supplementary Examinations	31 0 0	37 0 0	42 0 0	....	....	6 0 0
Students' Association	132 10 0	149 10 0	219 10 0	....	....	....
Apparatus and Equipment Trust Fund	1,000 0 0	....	1,000 0 0	....	....	....
Metallurgical Laboratory Trust Fund	1,258 14 0	1,268 14 0	1,050 18 0	....	....	....
Commonwealth Grant Fund	2,700 0 0	2,703 0 0	2,700 0 0	....	....	....
Mine Managers and Underground Supervisors	42 19 0	47 5 0	50 16 6	....	....	....
Sundries	55 6 0	132 0 7	66 9 0	....	....	....
Total	£6,709 5 0	£6,031 4 7	£6,940 15 0	£268 2 0	£237 0 0	£175 19 6

TABLE V.

Numbers of Students Paying Fees.
1961-1963.

Group No.	Description	Kalgoorlie						Norseman			
		1961	1962	1963				1963			
		Total	Total	Full Time	Part Time	External	Total	Full Time	Part Time	External	Total
1	Students under 18 Lecture notes plus Students' Association	77	100	8	96	....	104	....	28	....	28
2	Students 18-21 years Registration plus Lecture Notes plus Students' Association	82	97	12	88	....	100		20	....	20
3	Students over 21 Class plus Lecture Notes plus Students' Association	117	120	6	123	....	129	....	20	....	20
4	Returned Servicemen Exempt Class Fees	27	27	....	22	....	22	....	....	....	....
5	Staff. Exempt Registration or Class Fees	6	6	2	7	....	9	....	....	....	....
6	Scholarship Holders Exempt Registration or Class Fees	1	2	1	....	....	1	....	....	....	....
		310	352	29	336	Nil	365	Nil	68	Nil	68

TABLE VI.

Results of Annual and of Supplementary Examinations Based on Class Enrolments, 1959-1963.

	Kalgoorlie					Norseman				
	1959	1960	1961	1962	1963	1959	1960	1961	1962	1963
Class Enrolments = A.	916	939	804	945	931	140	146	139	160	140
Number of entries for Annual Examinations = B.	605	596	544	609	633	93	123	96	118	96
B/A per cent.	68	63	68	64	68	66	84	70	74	69
Number of passes at Annual Examinations as a per cent of A.	52	54	51	49	49	53	65	48	51	54
Number of passes at Annual Examinations as a per cent of B.	79	85	76	75	71	80	77	70	69	79
Number of passes at Annual Examinations and Supplementary Examinations as a per cent. of A.	54	55	53	52	52	57	66	54	53	56
Number of passes at Annual Examinations and Supplementary Examinations as a per cent. of B.	80	87	79	81	76	86	78	78	71	81

TABLE VII.

Students Sitting for Annual Examinations 1961-1963.

Course	Kalgoorlie						Norseman					
	1961		1962		1963		1961		1962		1963	
	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	109	93	95	93	98	95	5	100	10	100	4	100
Certificate	46	83	45	78	80	66	17	82	12	67	17	88
Technician	23	57	27	88	24	71	24	83	24	96	26	85
No Set Course	132	38	182	49	163	46	19	26	23	52	21	52
Totals	310	65	349	67	365	66	65	69	69	77	68	76

TABLE VIII.

Courses Completed, 1959-1963

Kalgoorlie and Norseman.

———	1959	1960	1961	1962	1963
Associateship Courses—					
Mining	6	3	2	1	3
Metallurgy	11	5	5	2	1
Engineering	4	4	10	3	2
Mining Geology	1	....	....	4	1
	22	12	17	10	7
Certificate Courses—					
Assayer's	3	2	1	6	1
Mine Manager's	3	1	1	1	2
Mine Surveyor's	5	....	11	6	5
Engineering Draughtsman's	1	2	2	2	4
Electrical Engineering	1	3	1	1	....
Mechanical Engineering	2	4	....	1	....
	15	12	16	17	12
Technician Courses—					
Engine Operation and Maintenance	4	2	1	1	1
Workshop Foreman's	1	1	1	1	....
Welding	5	2	1	....	1
Workshop Practice (Mechanical)	....	....	....	....	....
Workshop Practice (Electrical)	....	....	....	....	....
Mine Managers (2nd Class)	....	....	....	....	....
	10	5	3	2	2

TABLE IX.

Work Done on Samples Received from Prospectors and Others.

Kalgoorlie.

———	1959	1960	1961	1962	1963
Assay—gold	220	263	177	325	239
Assay—gold and other constituents	4	1	2	11	15
Assay—metals other than gold	16	35	23	46	57
Assay plus mineral determination	5	3	16	11	....
Mineral examination	140	94	117	138	108
Rejected or transferred to Metallurgical Laboratory pay	13	8	6	30	39
	398	404	341	561	458

TABLE X.

Kalgoorlie Metallurgical Laboratory.

Summary of Work.

———	1959	1960	1961	1962	1963
Investigations outstanding (January 1)	3	3	2	6	5
Investigations asked for (726-730 inclusive)	3	....	7	5	5
	6	3	9	11	10
Investigations completed	3	1	3	5	3
Investigations outstanding (December 31)	3	2	6	5	6
Investigations cancelled (726)	....	....	....	1	1
	6	3	9	11	10
Certificates issued (assays, analyses, etc.)	481	395	469	391	414

School of Mines of Western Australia.

APPENDIX 1.

ANNUAL EXAMINATIONS.

1963.

PASS LIST.

Passes are in Order or Merit.

Bracket denotes equal.

(*) Denotes year fee scholarship.

Chemistry P.

Pass:

Weir, D. J.
Kew, L. J.
Drazic, K. W.
Coleman, E. C.

Supp. Exam. Granted:

Douglas, J. C.
Burns, J. T.
Foxton, A. J.
Moon, J.

Chemistry Q.

Pass:

Livingstone, G.
Hobson, J. C.
Forrest, R. M.
Schultz, K. H.
McGushin, P. J.
Procter, J. D.
Renton, K. J.
{Greenhill, G. T.
{Leyland, E. C.

Supp. Exam. Granted:
Fiegert, J.
Goergenyi, G. J.
Golding, P. D.
Leslie, W. E.
Muze, K. A.
Pauley, J. J.
Walker, M. C.
Wallis, H. W.

Chemistry 1.
Credit:
*Brinsden, W. K.
Pass:
Sands, D. J.
Faulkner, D. A.
Botica, G. G.
Green, E. D.

Exemption Granted from Practical Work for 1964:
Ridley, R. H.

Analytical Chemistry 1.
Pass:
Head, D. J.
Absolon, V. J.

Analytical Chemistry 2.
Credit:
*Wills, M. F.
Pass:
Willcocks, P. W.
Black, N. C.

Mineral Dressing 1.
Credit:
*Lewis, C. J. B.
Tillotson, D. L.
Bright, A.
Pass:
Faulkner, D. A.
Fogarty, J. M.
Scarff, N. K.
George-Kennedy, R. J.
{Pascoe, R. G.
{Stokes, M. C.
Tonkin, D.
Lea, R. J.

Mineral Dressing 2.
Credit:
*Absolon, V. J.
Pass:
Gray, D.
Botica, G. G.
Willcocks, P. W.
Head, D. J.
Black, N. C.

Chemical Metallurgy 1.
Credit:
*Absolon, V. J.

Physical Metallurgy.
Pass:
Absolon, V. J.
Black, N. C.
Willcocks, P. W.

Assaying 1.
Credit:
*Head, D. J.
{Absolon, V. J.
{Ridley, R. H.
Pass:
Fogarty, J. M.
{Faulkner, D. A.
{Stokes, N. C.
Fiegert, J.
Bright, A. F.
Tillotson, D. L.
Flanagan, K. J.
Pascoe, R. G.
Supp. Exam. Granted:
Green, E. D.

Metallurgy A.
Credit:
*Moyle, P. A.
Pass:
McKenzie, R. R.
Godfrey, G.

Mathematics P.
Credit:
{*Abatematteo, G.
{*Byrnes, F. E.
Eaton, R. E.
Kelly, F. J.
Pass:
Rymer, H. A.
Curnow, W. D.
Hardy, E.
Sommerville, R. A.
Moriarty, M. T.
Barron, T. D.
Richter, Hans.
Usher, K. J.
Supp. Exam. Granted:
Honholt, D. A.
McLennan, R. J.

Mathematics Q.
Credit:
*Wallis, H. W.
Bowman, J.
Pass:
Muze, K. A.
Thompson, R. V.
Walker, M. C.
Douglas, J. C.
Miller, T. D.
{Kayombo, F. X.
{Kew, L. J.
Renton, K. J.
Greenhill, G. T.
Jones, G. J.
Forrest, A.
Reece, G. D.
Ryan, W. B.
Supp. Exam. Granted:
Erbe, J. D.
Livingstone, G.

Mathematics 1.1.
Pass:
Pervan, V. M.
Lewis, J. T.
Gilbert, N. B.
Crew, R. J.
Bussell, L. M.
Dombrose, J. S.
{Faulkner, D. A.
{Griffin, R. J.
Procter, J. D.
Lethlean, W. R.
Bailey, J. G.
Supp. Exam. Granted:
Green, E. D.
Wills, M. F.

Mathematics 1.2.
(Stat. Maths. Section Only.)
Credit:
*Fradd, J. F.
Pass:
Slocomb, J. H.
Younger, B. A.
Supp. Exam. Result.
Pass:
Lauri, J. M.
Excluding Stat. Maths.
Pass:
Pervan, V. M.
Supp. Exam. Granted:
Ralph, G. M.
Dombrose, J. S.

Mathematics 2.
Credit:
*Karcub, L. M.
Pass:
Maley, W. S.
King, R. M.
Supp. Exam. Granted:
Donovan, R. J.
Hobson, J. C.
Marshall, D. A.
McKenzie, J. H.

Physics "Q".
Pass:
Wallis, H. W.
Crew, R. J.
Jones, G. J. F.
Miller, T. D.
McGee, A. R.
{Erbe, J. D.
{Kayombo, F. X.
Forrest, A.
Lethlean, W. R.
Walker, M. C.
Bennetts, R. J.
Loxton, I. W.
Foxton, A. J.
Supp. Exam. Granted:
Douglas, J. C.
Muze, K. A.

Exemption Granted from Practical Work for 1964:
Douglas, J. C.
Muze, K. A.

Physics 1.1.
Credit:
*Flanagan, K. J.
Pass:
Brinsden, W. K.
{Tillotson, D. L.
{Tichelaar, P. D.
{McGushin, P. J.
{Murphy, A. J.
{Lea, E. J.
Procter, J. D.
{Dombrose, J. S.
{Gray, D. J.
{Bussell, L. M.
{Gilbert, N. B.
Faulkner, D. A.
Mand, E. D.
Dodge, G. J.
Supp. Exam. Granted:
Cluss, W. W.
George-Kennedy, R. J.
Griffin, R. J.
McNally, R. T.

Exemption Granted from Practical Work for 1964:
Cluss, W. W.
George-Kennedy, R. J.
Griffin, R. J.
McNally, R. T.

Physics 1.2.
Pass:
Tichelaar, P. J.
McGushin, P. J.
Kelly, J. P.
Procter, J. D.
Leyland, E. C.
Dombrose, J. S.
Lea, E. J.
Murphy, A. J.
Supp. Exam. Granted:
McNally, R. T.

Physics 2.
Credit:
*Maley, W. S.
Karczub, L. M.
Pass:
King, R. M.
{Hobson, J. C.
{Pearson, C. A. L.
Woolhouse, M. L.
Supp. Exam. Granted:
McIntyre, A. T.
McRostie, B. L.

Electronics.
Pass:
Egan, H. P.
King, R. M.
Maley, W. S.
Kelly, J. P.
Karczub, L. M.
Ralph, G. M.
Supp. Exam. Granted:
Hobson, J. C.
Woolhouse, M. L.

Engineering Drawing P.
Credit:
*Moriarty, M. T.
Richter, H. F.
Richter, Hans.
Pass:
MacKenzie, G. M.
Livingstone, G.
Moon, J.
Kops, J. N.
Allan, D. C.
Pinkerton, J. M.
Orr, P. D.
Ovens, D. M.

Engineering Drawing Q.
Credit:
*Thompson, R. V.
Wallis, H. W.
Reece, G. D.
Miller, T. D.
Tasker, H. E.
Hopkins, G. M. F.
Kelly, R.
Pass:
Burns, J. T.
Kew, L. J.
Walker, M. C.
Chamberlain, E. H. N.
Goldner, H.
Moon, J.
Muze, K. A.
Kayombo, F. X.
Sommerville, R. A.
Allan, D. C.
Golding, P. D.

Engineering Drawing 1.
Credit:
*Thompson, R. V.
Wallis, H. W.
Douglas, J. C.
McInerney, E.
Walker, M. C.
Fisher, J. A. S.
Foxton, A. J.
Mason, R. E.
Dombrose, J. S.
Griffin, R. J.
Cowin, A. B.
Pass:
Fogarty, J. M.
Dykstra, F. D.
Arjunan, G.
Karczub, L. M.
Forrest, A.
Jones, G. J. F.
Bailey, J. F.

Machine Design 1.1.

Credit:

*Maley, W. S.
Karczub, L. M.

Pass:

Fong, K. H.
Maguire, D. W.

Machine Design 1.2.

Credit:

*Fraser, B. J.

Pass:

{Baldwin, W. E.
{Blurton, L. N.
Willis, R. J.
Pearson, C. A. L.
Softley, M. D.
McRostie, B. L.
Donovan, R. J.
Egan, H. P.
Ghor, A..

Mechanical Engineering 1

Credit:

*Fraser, B. J.
Lewis, C. J. B.

Pass:

Maley, W. S.
Pearson, C. A. L.
Cumming, G. M.
King, R. M.
Karczub, L. M.
Dykstra, F. D.
Egan, H. P.
Softley, M. D.
Lubbock, F. N.
Cruickshank, A. C.
McRostie, B. L.
Shugg, P. J.
McNally, R. T.

Mechanical Engineering 2

Credit:

*Baldwin, W. E.
Willis, R. J.

Pass:

Blurton, L. N.

Electrical Engineering 1.

Credit:

*Schultz, K.
{Letts, I. R.
{Lewis, C. J. B.

Pass:

Egan, H. P.
Kelly, J. P.
Marshall, D. A.
Banks, F. R.
{Cumming, G. M.
{Kilderry, T. J.
{Dodge, G. J.
{Fong, K. H.
Woolhouse, M. L.

Supp. Exam. Granted:

Argus, J. C.
Chamberlain, H. I.
Cruickshank, A. C.
Pascoe, R. G.

Result of Deferred Supp. Exam.

Pass:

Botica, G. G.

Electrical Engineering 2.1.

Credit:

*Fraser, B. J.

Pass:

Miller, J. J.
Ralph, G. M.

Supp. Exam. Granted:

Softley, M. D.

Electrical Engineering 2.2.

Credit:

*Baldwin, W. E.

Pass:

Blurton, L. N.
Ghor, A.

Structural Engin'ring 1.1.

Credit:

*Lewis, C. J. B.
Marshall, D. A.
Schultz, K.
Kelly, J. P.
Cumming, G. M.

Pass:

Gard, L. A.
Maley, W. S.
Kilderry, T.
Karczub, L. M.

Structural Engin'ring, 2.1.

Credit:

{*Fraser, B. J.
{*Ralph, G. M.
Baldwin, W. E.
Miller, J. J.
Willis, R. J.
Slocomb, J. H.

Pass:

Softley, M. D.
Ghor, A.

Structural Engin'ring, 2.2.

Credit:

*Miller, J. J.
Baldwin, W. E.
Blurton, L. N.

Hydraulics.

Credit:

{*Baldwin, W. E.
{*Maley, W. S.
Egan, H. P.
Karczub, L. M.

Pass:

Blurton, L. N.
Leslie, W. E.
McIntyre, A. T.

Materials of Construction.

Credit:

*Roberts, R. M.

Pass:

McKenzie, J. H.
Bussell, L. M.
Maley, W. S.
Procter, J. D.
Karczub, L. M.
{Golding, P. D.
{Mason, R. E.
{Daws, D. C.
{Mand, E. D.
{Dombrose, J. S.
{Gilbert, N. B.
King, R. M.
Griffin, R. J.
{Harvey, J. S.
{Woolhouse, M. L.

Workshop Practice 1.

Credit:

*Slocomb, J. H.
Griffin, R. J.

Pass:

Roberts, R. M.
Fong, K. H.
Dombrose, J. S.
Kilderry, T. J.
McKenzie, J. H.
Patterson, B. S.
Walker, M. C.
Douglas, J. C.

Workshop Practice C.

Credit:

*Miller, J. J.

Pass:

Kew, J. A.
Harvey, J. S.
Maguire, D. W.

Internal Combustion Engines.

Credit:

*Williams, P. I.

Pass:

Kelly, E. J.
Jose, N. W.
Burston, K. J.
Harvey, J. S.
Jasper, R. G.
Fry, B. G.
Rourke, M. W.
Preen, N. J.
Rodgers, M. D.

Welding A.

Credit:

*Curnow, W. D.

Pass:

Tait, J. W.
Williams, P. I.
Godfrey, G.
Edwards, M. G.
Terrell, G. G.

Welding B.

Credit:

*Mitchell, R. G.
Reece, G. D.
McDairmid, P. J.
Senior, L. S.
Pinkerton, J. M.

Pass:

Moyle, P. A.
McKenzie, R. R.
Fry, B. G.

Engineering Drawing W.

Credit:

*Trembath, I. F.
Jose, N. W.
Moyle, P. A.

Geology Q.

Credit:

*Stodart, I. S.

Pass:

{Faulkner, D. A.
{Goergenyi, G. J.
Muze, K. A.
{Chamberlain, E. H. N.
{Dunstan, P. L.
Allan, D. C.
{Crew, R. J.
{Kayombo, F. X.
Jones, G. J.
Ridley, R. H.
Sommerville, R. A.
Green, E. D.
Boothman, C.
Tonkin, D.
Moriarty, M. E.

Supp. Exam. Granted:

O'Shaughnessy, D. J.
Timewell, R. J.

Geology 1.1.

Credit:

*Faulkner, D. A.
Tillotson, D. L.
Tichelaar, P. D.

Pass:

Scarff, N. K.
Renton, K. J.
Smurthwaite, A. J. N.

Geology 1.2.

Pass:

{Tichelaar, P. D.
{Tillotson, D. L.
Smurthwaite, A. J. N.
Pivac, A. M.
Magnus, E. R.

Exemption Granted from Practical Work for 1964:

Satapuntu, S.

Geology 2.1.

Pass:

Lea, E. J.
Quadrio, J. S.
{Lewis, C. J. B.
{Powell, P.
{Lea, R. J.
{Sands, D. J.
Loxton, I. W.
Fraser, P. G.
Hug, R. L.

Geology 2.2.

Pass:

Sands, D. J.

Supp. Exam. Granted:

Dykstra, F. D.
Murphy, A. J.

Exemption Granted from Practical Work for 1964:

Dykstra, F. D.
Murphy, A. J.

Mining A.

Credit:

*Byrnes, F.

Pass:

Rymer, H.
Abatematteo, G.
Hodge, F.

Mining 1.

Pass:

Fradd, J. F.
Ritchie, H. G.
McGee, A. R.
Lindfield, N. W.
Harken, R. M. (deferred pass from 1962)

Supp. Exam. Granted:

Turner, B. C.

Mining 2.1.

Pass:

Harken, R. M.
Lithgow, J. R.
Jongen, P. J. F. G.
Pivac, A. M.
George-Kennedy, R. J.
Magnus, E. R.
Taaffe, L. D.

Mining 2.2.

Pass:

Fogarty, J. M.
George-Kennedy, R. J.
Tarr, R. C.

Mining 3.

Credit:

*Argus, J.
Dykstra, F. D.

Pass:

Chamberlain, H. I.
{Hurley, B.
{Shugg, P. J.
Hennessy, R. M.

Mining 3A.
Pass:
Scarff, N. K.

Mine Ventilation 1.
Credit:
*Schultz, K.

Pass:
Lewis, C. J. B.
Flanagan, K. J.
Ritchie, H. G.
Banks, F. R.

Surveying 1.
Pass:
Quadrio, J. S.
McGee, A. R.
Lindfield, N. W.
Tarr, R. C.
McIntyre, A. T.
Younger, B. A.

Exemption Granted from Practical Work for 1964:
Fisher, J. A. S.
Allan, D. C.

Exemption Granted from Attendance at Lectures for 1964:
Boschis, A.

Supp. Exam. Granted:
Allan, D. C. (Paper A)
Reid, R. H. J.

Surveying 2.1.
Credit:
*Harken, R. M.
Bain, W. B.

Pass:
Magnus, E. R.

Supp. Exam. Granted:
Sands, D. J. (Paper C.)

Surveying 2.2.
Credit:
*Lauri, J. M.
Loxton, I. W.

Pass:
Goode, W. D.
Satapuntu, S.
Bain, W. B.

Mining 3B.
Credit:
*Murphy, A. J.

Pass:
McNally, R. T.

English Q.
Pass:
McInerney, S. A.
Bennetts, R. J. R.
{Wallis, H. W.
{Forrest, A.
Merrick, M. D.
{Brinsden, W. K.
{Forrest, R. N.
{Jones, G. J. F.
{Green, E. D.
Bailey, M.
Fraser, H. J.
Loxton, I. W.
Egan, A.
Fiegert, J.
{Walker, M. C.
{Griffin, R. J.
{Golding, P. D.
{Muze, K. A.
{Procter, J. D.
{Davies, D.
{Woolhouse, M. L.
{Lethlean, W. R.
Morocz, G.

Supp. Exam. Granted:
Fisher, J. A. S.
Kayombo, F. X.
Wood, J. McM.
Sullivan, I.

English 1.
Credit:
*Lewis, C. J. B.
Fogarty, J. M.
Absolon, V. J.

Pass:
Banks, F. R.
Dodge, G. J.
Gray, D. J.
Pearson, C. A. L.
Kelly, J. P.
Blurton, L. N.
George-Kennedy, R. J.
McNally, B. T.
Sloan, R. B.

Workshop Practice B.
Pass:
Giles, K. W.
Giles, T. E.
{Horne, R. H.
{Rose, F. W.
Johnson, R.
Bottegal, J.
Coles, J. E.

Electrical Theory B.
Pass:
Rasmussen, G. L.
Johnson, R.
Murphy, R. J.
Rose, F. W.
Bottegal, J.
Freeman, P. G.

Steam Engine Driving.
Credit:
*Skinner, K. J.

Pass:
Underwood, J. W.
Benoit, A. L.
Coles, J. E.
Green, T. D.
Giles, K. W.
May, C. F.

Supp. Exam. Granted:
Prime, G. G.

Welding A.
Credit:
*Jones, F. K.

Pass:
Giles, T. E.
Murphy, R. J.
Foote, S. P.
Murrie, A. W.
Philippe, G. R.
Starcevich, R. F.
Green, T. D.
Jenkins, L. K.
Sharpe, D. M.

Exemption Granted from Attendance at Lectures for 1964:
Watson, R. M.

Welding B.
Credit:
*Temple, E. D.

Pass:
McEwan, J.
Willoughby, B. G.
Giles, W. K.

Geology 1.1.
Pass:
Cooper, A. W.
Cook, G. J. S.
Stewart, B. A.

Mining 1.
Pass:
Stewart, B. A.
Sweet, K. A.
Cook, G. J. S.
Daly, P. R.
Cooper, A. W.
Swain, G. B.

Supp. Exam. Granted:
O'Connor, G.

Mine Ventilation.
Pass:
Lea, R. J.
Hug, R. L.
{Denison, J. L.
{Powell, P.

Electrical Drawing B.
Credit:
*Rasmussen, G. L.
Bottegal, J.

Pass:
Murphy, R. J.
Johnson, R.
Freeman, P. G.
Jenkins, L. K.

Mining 3A.
Pass:
Denison, J. (deferred pass from 1962)

Physics Q.
Credit:
*Rasmussen, G. L.

Pass:
Kerr, P. H.

School of Mines—Norseman.

ANNUAL EXAMINATIONS.

PASS LIST.

Mathematics P.
Credit:
*Eyre, H. R.

Pass:
Pitchers, P. W.
Darch, R. J.
Sharpe, D. M.

Mathematics Q.
Pass:
Cook, G. J. S.
{Hill, A. J.
{Rose, F. W.
Churchill, W. G.
Ibbotson, G.

Mathematics 1.1.
Pass:
Rasmussen, G. L.

Mathematics B.
Pass:
Foote, S. P.
Perkin, D. A.

Engineering Drawing P.
Credit:
*Farr, R. G.

Pass:
Jones, E. J.
Temple, E. D.
Watson, R. M.
Philippe, G. R.

Engineering Drawing Q.
Credit:
*Foote, S. P.

Pass:
Giles, T. E.

Engineering Drawing 1.
Pass:
Reher, R.
Eyre, H. R.

SUPPLEMENTARY EXAMINATIONS.

FEBRUARY, 1963.

The following students passed in the subjects listed below:—

* Denotes deferred finals taken in February, 1963.

KALGOORLIE

Chemistry P.
Baldwin, N. G.
*Hicks, D. C.
Moriarty, M. E.

Chemistry 2.
Black, N. C.

Mineral Dressing 1.
Flanagan, K. J.
Kozuh, D.

Mathematics P.
Argus, A. A.

Mathematics 1.
*Magnus, E. R.

Mathematics 2.
Cumming, G. M.
Egan, H. P.

Physics Q.
Golding, P. D.

Physics 1.1.
Fong, K. H.
*Magnus, E. R.
Maley, W. S.
McRostie, B. L.
Argus, J. C.

Physics 1.2.
*Magnus, E. R.
Argus, J. C.

Physics 2.
Leslie, W. E.

Electrical Engineering 1.1.
Jongen, P. J. F. G.
McGushin, P. J.

Structural Engin'ring 1.1.
Satapuntu, S.

Machine Design 1.1.
Daws, D. C.
Keogh, C. E.

Geology 1.2.
Lauri, J. M.
Loxton, I. W.
Mackay, I. D.

Mining 1.
Thomas, G. N.

Mining 2.1.
Attrill, D. M.

Mining 3 (Section B only)
Henderson, G.

Surveying 2.1.
Attrill, D. M.
Loxton, I. W.

English Q.
Renton, K. J.

NORSEMAN

Metallurgy A.
*Prime, G. G.

Geology 1.2.
Moffat, B.

Surveying 1.
O'Connor, G.

BULLFINCH

Surveying 2.2.
*Blackley, T.

Geology 1.2.
*Blackley, T.

School of Mines of Western Australia.

APPENDIX 2.

SCHOLARSHIPS AND PRIZES, 1963.

MINES DEPARTMENT.
Entrance Scholarship: L. J. Molloy.
Senior Scholarship: M. C. Walker.

CHAMBER OF MINES PRIZES.
Mining: J. F. Fradd.
Metallurgy: D. A. Faulkner.
Engineering: H. P. Egan.
Mining Geology: No award.

SCHOOL OF MINES STUDENTS' ASSOCIATION SCHOLARSHIPS.
Mining: K. Schultz.
Metallurgy: D. J. Gray.
Engineering: B. J. Fraser.
Mining Geology: J. M. Fogarty.

INSTITUTE OF MINING SURVEYOR'S PRIZE.
£10 Prize: No award.
£5 Prize: R. M. Harken.

SOCIETY OF THE W.A. SCHOOL OF MINES ASSOCIATES' PRIZE.
R. V. Thompson.

REG. DOWSON SCHOLARSHIPS.
Group A: H. R. Eyre.
Group B: R. J. Murphy.

ROBERT FALCONER PRIZES.
First Prize: No award.
Second Prize: No award.

C. A. HENDRY PRIZE.
V. M. Pervan.

WESLEY LADIES' GUILD.
H. W. Wallis.

APPENDIX 3.

Kalgoorlie Metallurgical Laboratory.

By E. Tasker, A.W.A.S.M. (Met.), A. M. Aust. I.M.M., Senior Research Metallurgist.

INTRODUCTION.

Three reports of investigations and four hundred and fourteen certificates of testing or analyses were issued during the year. Brief descriptions of the investigations are included in the report.

For further information regarding these reports apply to:

The Secretary,
Commonwealth Scientific and Industrial Research Organisation,
314 Albert Street,
East Melbourne, C.2,
Victoria.

from whom copies of the reports can be obtained, usually six months after date of issue.

In addition to the reports issued, six other investigations were approved and test work was in progress.

Numerous inquiries dealing with technical problems of people engaged in mining and other industries were handled during the year. A considerable amount of work was carried out on various projects for the Metallurgical Committee of the Chamber of Mines of Western Australia.

COMPLETED INVESTIGATIONS.

Report No. 723

Treatment tests were carried out on a cupiferous-gold tailing from Gabanintha, Western Australia. However, no economical treatment method could be devised.

Report No. 724

Beneficiation tests were carried out on a sample of stockpiled Manganese ore screen reject material from Woodie Woodie, Western Australia. Sink-float treatment could recover 73 per cent. of the manganese in a concentrate assaying 50 per cent. Mn.

Report No. 727

Examinations were made of products from a tin concentrator at Spear Hill, Cooglegong, Western Australia.

INCOMPLETE INVESTIGATIONS.

Report No. 716

Further test work was carried out on a sulphide-gold ore from Fimiston, Western Australia. Four interim reports have been issued.

Report No. 721.

Beneficiation tests were carried out on an iron ore from the Tallering deposit, Western Australia.

Report No. 725

Beneficiation tests were carried out on a low-grade cement lime-rock from Fremantle, Western Australia, and an interim report was issued.

Report No. 728

Test work was carried out on upgrading low-grade limestones from Fremantle, Western Australia. An interim report was issued.

Report No. 729

Test work was carried out on an auriferous chalcopyrite concentrate from the Paris Gold Mine, Widgiemooltha, Western Australia.

Report No. 730

Treatment tests were made on a tin-tantalum concentrate from Spear Hill, Cooglegong, Western Australia.

Kalgoorlie Metallurgical Laboratory.

Summary of Year's Work, 1963.

Report No.	Owner	State	Locality	Ore Type	Type of Investigation	Confidential Until	Number of Metallurgical Tests	Number of Assays Gold	Number of Assays Other
723	Gaban Syndicate, Perth	W.A.	Gabanintha	Gold-copper Tailings	Treatment Tests	7/7/63	26	68	100
724	Northern Mineral Synd., Perth	W.A.	Woodie Woodie	Manganese	Beneficiation	19/9/63	7	....	50
726	Cancelled	....	....	....	....	....	....	....	....
727	Northern Mineral Synd., Perth	W.A.	Cooglegong	Tin	Examination	25/1/64	6	....	30
	Certificates Nos. 2097–2250, 2252–2344, 2346–2512	....	....	....	....	....	....	1,215	853
....	Free Assays	....	....	....	....	....	....	260	52
....	School of Mines	....	....	....	....	....	....	....	10
						Totals	39	1,543	1,095
	THE FOLLOWING INVESTIGATIONS WERE INCOMPLETE OR PENDING AT DECEMBER 31, 1963								
716	Gold Mines of Kalgoorlie, Fimiston	W.A.	Fimiston	Gold	Treatment Tests	....	48	310	220
721	Western Mining Corp., Kalgoorlie	W.A.	Tallering	Iron	Beneficiation	....	24	....	200
725	Cockburn Cement Pty. Ltd., Perth	W.A.	Fremantle	Cement Limerock	Beneficiation	....	6	....	38
728	Swan Portland Cement Ltd., Perth	W.A.	Fremantle	Limerock	Beneficiation	....	12	....	76
729	Paris Gold Mine Pty. Ltd., Widgiemooltha	W.A.	Paris	Gold	Treatment	....	30	100	15
730	Northern Mineral Synd., Perth	W.A.	Cooglegong	Tin-Tantalum	Treatment	....	30	....	50
						Totals	189	1,953	1,694

DIVISION VI

Annual Report of the Inspection of Machinery Branch of the Mines Department for the Year 1963

The Under Secretary for Mines:

For the information of the Hon. Minister for Mines I submit the report of the Deputy Chief Inspector of Machinery in the administration of the Inspection of Machinery Act, 1921-1958, for the year ending 1963.

Chief Inspector of Machinery.

Section 1.

INSPECTION OF BOILERS, MAINTENANCE, ETC.

(See Returns Nos. 1, 2 and 3.)

Under the Act "Boilers" means and includes—

(a) any boiler or vessel in which steam is generated above atmospheric pressure for working any kind of machinery, or for any manufacturing or other like purpose;

(b) any vessel used as a receiver for compressed air or gas, the pressure of which exceeds 30 lb. to the square inch, and having a capacity exceeding five cubic feet; but does not include containers used for transport;

(c) any vessel used under steam pressure as a digester; and

(d) any steam jacketed vessel used under steam for boiling, heating, or disinfection purposes.

It also includes the setting, smoke stack, and all fittings and mountings, steam or other pipes; feed pumps and inspectors 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 200 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, 2338 were not in service.

Return No. 3.

This contains a summary of operations for the year. The manufacture of boilers in this State for export has continued with a slight decrease during this year, compared with 1962. Ninety-four boilers were exported to the Eastern States and four were sent overseas. There was a small drop in the number of boilers and pressure vessels imported from the Eastern States but an increase of almost 50% in the number of vessels from countries outside Australia. Most of the latter were for installation in the lub. oil extensions to BP Kwinana Refinery and Alcoa Aluminium Refinery. Both are plants which use vessels peculiar to their own particular industry. The use of refrigeration in food processing and air conditioning is widespread and thus the need for associated pressure vessels has been maintained.

Return No. 1.

Showing the number of boilers of each type, and country of origin of new registrations for the year ended 31/12/63.

	U.S.A.	United Kingdom	Eastern States	Canada	Holland	Norway	Western Australia	Unknown Resources	Total
Ret. Multi Stat. Int. Fired	....	....	....	....	....	....	117	....	117
Digester	....	....	1	....	....	2	8	....	11
Vulcaniser	4	....	3	....	....	....	11	....	18
Steam Jacket Vessels	....	....	5	....	3	....	16	....	24
Sterilizer	....	....	16	....	....	....	34	....	50
Air Receiver....	4	3	47	....	....	....	98	13	165
Gas Receiver	10	6	8	8	....	....	52	1	85
Autoclave	....	1	4	....	....	....	4	....	9
Vert Stat.	....	....	1	....	....	....	2	....	3
Ret. Multi. Stat Unfired	....	....	....	....	....	....	....	1	1
Cornish	....	....	....	....	....	....	6	....	6
Water Tube....	....	....	3	....	....	....	1	....	4
Waste Heat....	....	1	....	....	....	....	....	....	1
Cylindrical Ext. Fired	....	....	....	....	....	....	....	....	....
Not Elsewhere Specified	....	....	3	1	....	....	....	....	4
Total	18	11	91	9	3	2	349	15	498

Return No. 2.

Showing Classification of various Types of useful boilers in proclaimed Districts on 31/12/63.

Types of Boilers	Districts Worked from Perth	Districts Worked from Kalgoorlie	Total
Lancashire	42	23	65
Cornish	232	60	292
Semi Cornish	14	1	15
Vert. Stationary	406	41	447
Vert. Port	33	11	44
Vert. Multi Stat.	46	4	50
Vert. Multi Port	8	1	9
Vert. Pat Tubular	49	....	49
Loco. Rect. F/Box Stat.	70	20	90
Loco. Rect. F/Box Port.	150	17	167
Loco. Circ. F/Box Port.	90	2	92
Locomotive	81	11	92
Water Tube	551	59	610
Ret. Multi U/fired Stat.	259	7	266
Ret. Multi U/fired Port.	....	5	5
Ret. Multi. Int. Fired Stat.....	201	6	207
Sterilisers	611	39	650
Autoclaves	96	2	98
Digesters	310	7	317
Gas Receivers	540	....	540
Air Receivers	2,207	618	2,825
Vulcanisers	444	10	454
Steam Jacketed Vessels	690	15	705
Not Elsewhere Specified	203	5	208
Total Registration Useful Boilers	7,333	964	8,297
Total Boilers out of use, 31/12/63	1,725	613	2,338

Return No. 3.

Showing Operations in Proclaimed Districts during Year ended 31/12/63.

Boilers	Districts Worked from Perth	Districts Worked from Kalgoorlie	Total	
			1963	1962
Total number of useful boilers registered	7,333	964	8,297	7,957
New Boilers registered during year	497	11	508	510
Boilers inspected thorough	4,662	344	5,006	4,900
Vessels exempt under Act constructed for export thorough	....	....	....	....
Boilers inspected working	963	7	970	1,075
Boilers condemned during year temporarily	4	....	4	1
Boilers condemned during year permanently	66	1	67	78
Boilers sent to other States during year	94	....	94	107
Boilers sent from other States during year	87	....	87	103
Boilers sent from other countries during year	42	....	42	25
Boilers sent to other countries during year	2	2	4	6
Transferred to other Departments	2	....	2	....
Transferred from other Departments	....	....	....	3
Re-instated	2	....	2	4
Converted	....	....	....	2
Number of notices of repairs issued during year	616	31	647	528
Number of certificates issued, including those issued under Section 30 during year	4,645	344	4,989	4,875

MAINTENANCE AND MISCELLANEOUS.

The maintenance and operation of boilers in this State has generally continued to be most satisfactory. There are of course, and I am afraid always will be, a hard core minority of boiler owners and users whose running and maintenance from both ignorance and negligence leave much to be desired. Generally from this group arises the necessity for heavy repairs, water shortages and damaged boilers. Fortunately there were very few boiler mishaps in the current year and none resulted in serious injury to persons.

A further reduction in the number of boiler and pressure vessels in use in the Goldfields Districts has taken place with the closing down of the Kalgoorlie Electric Power & Lighting Corporation, the Sons of Gwalia Gold Mine and the activities of Great Western Consolidated N.L. in Yilgarn. Counterbalancing this is activity in Kwinana area with the installation of a lubricating oil plant at BP Kwinana Refinery, and a large steam generation plant and numerous pressure vessels at Western Aluminium Refinery. A further steam generation plant and pressure vessels have been erected at Bunbury for Laporte Titanium. In addition the metropolitan area industrial complex continues to expand. Overall there was an increase of over 300 boilers and pressure vessels registered.

Section 2.

EXPLOSIONS AND INTERESTING DEFECTS.

I am pleased to report that there was no explosion of any pressure vessel during 1963, but several occurrences during the year are considered worth some elaboration.

A.

This is a follow up of section B in the report for 1963 and concerns the three similar return multi tubular internally fired boilers installed in a brewery. At the time of writing last year's report after repeated trouble from leaking tubes in the back end, it was thought that the matter had been overcome by welding the tubes at the back end pass. After approximately 13 months free from trouble leakage was again apparent at the back end. All second pass tubes were removed and the tube plate was dye checked revealing radial cracks from eight tube holes. The worst crack, from which the leakage had been coming, extended across the tube hole landing and approximately 1 inch down the external face of the tube plate and ½ inch down the internal face. No damage was evident to the front tube plate. In order to effect repairs it was decided to renew both tube plates. The tube plates were cut away from the shell and furnace tube, prior to which a careful inspection had been made of the furnace to tube plate joint and no evidence of cracking due to working of the joint or any other defect was evident. However when the ends of the furnace were being prepared for re-fitting, and all the old weld metal was removed circumferential cracks were found approximately 1 inch from each end extending completely round the furnace tube to a maximum depth 3/16 in. To overcome this a section 14 inches long at each end was replaced.

The initial fault of the cracked tube plate was in my opinion due to the reasons previously given being still present plus the fact that the tube holes had suffered from numerous re-expansions of tubes. The seal welding of the tubes at the back end could well be contributory as it was only possible to put on a small fillet between the tube beading and the tube plate.

The cracks in the furnace tube were in a position corresponding to the toe of the sealing weld applied internally between the furnace and tube plate. I consider this to be a typical toe crack initiated by the small fillet weld and that it provides support for dispensing with small fillet seal welds, particularly when an adequate strength weld has been put in from the other side of the joint.

After the aforementioned repairs had been carried out which included welding the second pass tubes at the back end in accordance with A.S. CB1 requirements, the boiler was reinstalled and worked satisfactorily until replaced after approximately four months further service. Subsequent inspection has shown no fault.

B.

This incident concerns the springing of tubes in a return multi tubular under fired boiler due to shortage of water. The boiler was fitted with a feed pump control operating at high and low water levels and connected on the low side to a Klaxon to indicate when the pump failed to cut in. It was possible to shut the Klaxon off while the water was being pumped up to a safe level after low water conditions had been present. This had apparently happened prior to the incident under discussion but the Klaxon had not been switched in again and there was consequently no audible alarm when the low water condition occurred.

From the foregoing these points emerge which in conjunction contributed to the mishap whereas singly damage to the boiler possibly would not have resulted. Firstly there was lack of supervision to allow the shortage of water in the first instance. No doubt engendered by the fact that the boiler had some automatic control. Secondly the feed pump did not cut in on low water due to mechanical fault. Thirdly the audible alarm did not sound as it had been left switched off. The first and third of the above points can be attributed to human error, which is an ever present factor in these mishaps and the second point probably to lack of maintenance, another common fault.

C

The boiler involved in this incident was again a multi tubular under fired type used to supply process steam to the large autoclaves some distance away.

The cause of the low water condition and sprung tubes at the back end was due to the neglect of the boiler attendant. The boiler water was being treated which resulted in a heavy build up of solids in the boiler. In addition to daily blow downs it was the practice at the end of the week to give the boiler several heavy blow downs. In this case the attendant opened the blow down, then went to check his autoclaves. While at the autoclaves he noticed something requiring attention and proceeded to attend to this, meanwhile forgetting that the boiler was blowing down. On returning to the boiler the water was out of sight and it was later found that damage had resulted.

There appear to be two causes of this accident, the first and prime factor being (1) that the attendant left his boiler when the blow down valve was opened, and forgot same. The second factor being (2) other duties given to the boiler attendant some distance away from the location, which is all too common among employers who feel that if the boiler attendant is not engaged in physical effort he should be found something else to do. Although not an excuse it does somewhat mitigate the culpability of the attendant.

D.

The boiler involved in this case was a return multi tubular internally fired with automatic control. Once again, fortunately the damage due to low water was restricted to tube leakage. The water shortage was found to be due to classical, almost standard reasons as follows:—

(1) Failure of the operator (certificate not required) to follow standard operating instructions with regard to regular blow down of float control chamber. This led to a false level in the float chamber and the gauge glass mounted thereon and consequently the feed pump was not brought into operation.

(2) Poor operating technique and lack of maintenance led to the other gauge glass mounted on the shell on the opposite side being found blocked.

I can only reiterate and stress the need for strict adherence to makers' operating instructions and the simple basic principles of boiler operation and maintenance which is the usual bug bear in small single boiler installations.

E.

This mishap, which also resulted in a low water condition and tube springing with damage necessitating the renewal of all tubes, also concerned a Return Multi tubular internally fired boiler. At the time of the mishap the regular operator (certificated control not required) was on holidays. In his absence the boiler was in charge of the yardman who in addition to being unskilled in anything connected with boilers was an Italian and had a very limited knowledge of English. The regular operator had left a list of instructions on procedure for checking controls, blowing float chamber and relighting every morning.

Investigation, after it had been discovered that the boiler was short of water, indicated that all controls were in good condition but apparently after blowing down the float control chamber the operator had left the three way cock in the incorrect position. It was in such a position that the water leg was blowing down continuously. However water must have been trapped in the float control chamber as the low water flame cut out did not operate and severe overheating occurred.

The comments on the previous mishap "D", are equally applicable to this case with an additional note concerning language difficulties which have increased with the influx of migrants to this country, so extra care must be exercised by owners to ensure that such attendants fully understand what is required of them before they are left in charge.

Section 3.

INSPECTION OF MACHINERY.

(See Returns Nos. 4, 5 and 6.)

At the expiration of the year 48,012 groups of machinery were in the register. This indicates an increase of 2,500 groups in comparison with the figure for the previous year. Lift figures reveal an increase of 17 installations.

ACCIDENTS TO MACHINERY.

In this category four mishaps appear worthy of noting. They are concerned with mobile cranes. One a fly jib failure and the other three concern similar type cranes on which cracking was found in the chassis members.

The crane in the first incident was crawler mounted, fully slewing, fitted with a 90 ft. main jib and 30 ft. fly jib at the time. The makers' rated load under these conditions was 11,500 lbs. at minimum radius. A machinery section weighing approximately 10,500 lbs. had already been lifted and lowered from about 70 ft. It was then picked up again to be repositioned, necessitating a lift of approximately 3 ft. and slewing of the crane. During the slewing operation the centre section of the fly jib collapsed resulting in slight damage to the machinery load and no injury to persons.

Investigation found no evidence of misuse or abuse of the crane prior to accident. Examination of the broken section of fly jib revealed that the high tensile steel chords had a wall thickness 30% less than the required design thickness. This seems to be the main cause of the failure but from calculations made with the actual thickness it appears that the load under which the jib failed was only 38% overload giving a factor of 1.38 which is extremely low.

From the foregoing it appears that there was laxity of supervision by the manufacturer both when the material was being selected from store and also in fabrication. There also appears to be a tendency by some crane manufacturers to reduce factors of safety in their efforts to lighten the weights of crane members while maintaining the load ratings.

The second series of incidents are all very similar and occurred in identical model cranes. These cranes were fully slewing truck mounted with jib lengths fom 30 to 110 ft.—maximum rated load of 50,000 lb. at 10 ft. radius using 30 ft. jib.

Prior to acceptance testing of this crane on site the inspector was checking the crane and outrigger when it was found that the welding on all four outrigger housings had cracked at the top inner corner. Under test the cracks did not appear to open up. When test loads were applied the main chassis twisted and one rear outrigger was found to be out of horizontal alignment. The difference in level between the front and rear outriggers was approximately 3 inches. Further luffing out of the jib increased the twisting of the chassis and buckling was evident in the light cover plates bolted to the main chassis. Further testing was halted in this stage. Enquiries elicited that the crane had either been overloaded or one outrigger had been extended on soft ground and sank under load. Inspection of the chassis member revealed seven cracks in the chassis at or near where a section of the R.S.J. had been cut out to clear the rear wheel axle assembly.

Two other cranes of similar type were then examined and similar cracking of the chassis though to a lesser degree was found in both cases. Enquiries concerning one of the cranes revealed that it had been overloaded but not grossly.

The investigating Inspector stated as follows—

> It is my considered opinion that such failures should never occur in this part of a crane. All cranes of this type should be designed that the crane should tip first long before any chassis failure could occur, and it is obvious that this chassis in relation to the rest of the crane and its capacities was underdesigned.

Repairs were ordered to all these cranes resulting in considerable strengthening of the chassis in the affected area. Further testing on completion of repairs showed no sign of chassis distortion.

This again indicates the pitfalls of trying to cut down the weight of these cranes whilst maintaining high load ratings. Mobile cranes suffer badly from hard working conditions under adverse circumstances engendered by rough areas on building and construction sites, often poor driving and overloading. It is therefore necessary that construction be rugged and certainly not erring on the side of under designing.

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, 1963.

Classification	Districts Worked from Perth	Districts Worked from Kalgoorlie	Totals 1963	Totals 1962
Number of groups driven by Steam Engines	114	373	487	495
Number of Groups driven by Oil Engines	3,107	728	3,835	4,133
Number of Groups driven by Other Power	89	195	284	140
Number of Groups driven by Electric Motor	40,418	2,988	43,406	40,744
Total	43,728	4,284	48,012	45,512

Return No. 5.

Showing Operations in Proclaimed Districts During Year Ended 31st December, 1963. (Machinery Only).

——	Districts Worked from Perth	Districts Worked from Kalgoorlie	Totals 1963	Totals 1962
Total Registrations Useful Machinery	43,728	4,284	48,012	45,512
Total Inspections made	30,517	3,460	33,977	30,646
Certificates (Bearing Fees)	6,354	525	6,879	6,253
Notices issued (Machinery Dangerous)	780	51	831	772

Return No. 6.

Showing Classification of Lifts on 31st December, 1963.

Types	How Driven	Total 1963	Total 1962
Passenger	Electrically Driven	303	291
Goods	Electrically Driven	114	124
Goods	Belt Driven	....	3
Goods	Electric Hydraulic Driven	13	1
Service	Electrically Driven	112	106
Service	Electric Hydraulic Driven	1	1
Escalators	Electrically Driven	28	28
		571	554

Section 4.

PROSECUTIONS FOR BREACHES OF THE ACT.

There were no prosecutions to report.

Section 5.

ACCIDENTS TO PERSONS.

Return 7 and 7a record accidents to persons with 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 minor character.

Return 7b shows accidents caused by machinery not subject to registration by this Department but investigated under provisions of Section 50 of the Act.

The overall total of occurrences shown in the three returns numbers 85.

During the year two (2) fatalities were investigated, one in each category.

Case A.

This accident, investigated by this Department under Section 50 of the Act involved a portable circular saw being used for tree clearing on an agricultural property by the owner. Unfortunately a fatality resulted.

The victim was working on his own and consequently there was no eye witness to the mishap. From investigations after the occurrence it appeared that his method of working was as follows—

The saw, a 28 in. blade driven by 2 vee belts, was set up with the blade horizontal. The growth being cleared was small trees and scrub. From reconstruction after the accident it appeared that at the time he was felling a tree with a trunk 15 in. diameter and approximately 25 ft. high. The method used to fell the tree was to cut half way through the trunk, on the side to which the tree would fall, then move the saw and cut through from the opposite side. It appeared that in this case he had misjudged the side to which the tree would fall and as he put the second cut into the trunk the tree started to fall towards the saw. It is thought that the victim left the controls of the saw and attempted to guide the tree away from the machine. He was forced backwards by the tree, his right leg contacted the saw blade and was severed. He then collapsed over the shaft and vee belt drives and the tree fell over the saw too. The combined weight of the victim's body and the tree was sufficient to stall the engine, as it was found later that the throttle was still in the open position. It is not known at what time the accident occurred but when the unfortunate victim was discovered he was already dead.

Case B.

This second fatal accident resulted from the failure of a rim runner mounted on the top rim of a 150 ft. high chimney stack. The victim was suspended in a bosun's chair from the rim runner and dropped approximately 90 ft. to his death.

The rim runner was made up of 2 x ⅜ in. flat mild steel shaped to form a U with legs approximately 19 in. long. A 6 in. diameter pulley was mounted on a pin through both legs which located it in the bottom of the U. In use the rim runner was inverted so that the legs of the U straddled each side of it.

By means of a shackle a pulley block was attached to the outside leg. Through this was reeved a line from a winch which had another pulley block attached to the free end. Again through this block was reeved a further wire rope from another winch and to the end of this rope was fastened the bosun's chair in which the deceased was sitting. A tail rope was attached to the bosun's chair.

Just prior to the accident the deceased was removing temporarily a guy rope from the stack as it was in the way of the re-erection of the ladder up to the top of the stack. A fellow rigger was standing at ground level holding the tail rope. A fairly brisk wind was blowing at the time.

The guy rope had been disconnected by the deceased and attached to the bosun's chair. The chair was then being lowered so that the guy rope could be removed. As the chair was lowered the guy rope fouled on the section of ladder already erected. Lowering was stopped and a sign made for the tail rope to be used to pull the bosun's chair and deceased across towards the ladder. The guy wire had just been freed when the rim runner carried away and all the rigging together with the victim fell.

The rim runner was inspected after the mishap and it was found that both legs had spread so that the included angle was approximately 120°, the bending occurring at the weakest part, i.e. where the pulley pin passed through the legs.

From the investigation it is considered that a number of factors led to the accident:—

(1) The rim runner was not a good fit over the top of the stack so that it was canted at an angle which in turn put a bending load on the runner leg.

(2) The design of the rim runner legs was more than adequate for any anticipated load in direct tension but had little resistance once bending was present. The rim runner had been in use for some time on similar jobs but not at such a height before.

(3) The method of rigging with two blocks and winches quadrupled the load at the bosun's chair when transmitted to the rim runner.

(4) It is not known what load was being applied on the tail rope attached to the bosun's chair but some additional load was being brought to bear.

(5) There could have been an impact loading from the freeing and dropping of the stack guy as the slack was taken up.

(6) Some wind loading was no doubt present.

In the foregoing there are too many unknowns to pinpoint the exact cause but most likely it was a combination of them all. Once the initial deformation of the rim runner leg started it would continue even with reduced loads.

The need for gear properly designed by people with an appreciation of how the loads are applied and where stiffening is necessary is shown by this accident.

Case C.

The machinery concerned in this accident was a set of four conveyor screws approximately 15 ft. long, 6 in. diameter and approximately 6 in.-8 in. apart, set in the bottom of a saw dust bunker for the purpose of feeding saw dust fuel to a boiler.

It was found during investigation that it was the practice for the trimmer to go into the bunker at the end of each shift to clear out the accumulated saw dust from between and under the screws. This was done with the screws regulated to the slowest speed of 7½ r.p.m. The screws were uncovered except for a support bearing set at mid-length on each screw.

The victim in this case was following the above procedure when his right trouser leg was caught between one of the screws and the support bearing. This threw him off balance so that he fell across the adjacent screw where his right arm was caught between the screw and its support bearing. He was in this position for approximately 15 minutes before discovery and suffered such injuries to his right arm that it was amputated at the shoulder, and his right leg was amputated below the knee.

This accident was due to unsafe methods adopted to clear sawdust from the screws while they were in motion, and once again emphasises the ever present hazards of working around moving shafting etc.

Case D.

The machine involved in this accident was a press set up for the closing operation on a fly wire housing. The clutch mechanism was operated through a linkage by a pneumatic cylinder which was actuated by valves requiring the use of both the operator's hands thus keeping them clear of die during operations. The foot pedal was disconnected.

The accident occurred when the machine failed to stop after one cycle and the victim had both hands caught by the die, resulting in the loss of the first two joints from all eight fingers.

It was found that the clutch remained engaged due to the ⅜ in. diameter screwed locking pin on the cam plate shaft collar extending the dimple originally drilled in the shaft. It had extended to become a keyway 1⅛ in. long allowing sufficient end movement in the shaft to engage the clutch although the pneumatic cylinder was in the "off" position.

It was decided that probably the loadings on the locking system employed on the collars and adjustments in the link gear induced by 80 p.s.i. air, actuating the pneumatic cylinder, were excessive. At first it was proposed that a small cylinder be used to try the above theory but eventually a standard fence type guard supplied by the maker was installed. I consider there is merit in the excessive air pressure theory above and that it indicates the necessity for thorough examination of all components in the design of such mechanism.

Case E.

The machinery concerned in this accident was also a metal stamping press being used at the time to press "drawer fronts". This machine was fitted with an interlocking device which required both hands to operate handles well clear of the table before the foot pedal, which set the press in motion, could be used.

The injured party claimed that the press repeated after he had released the locking handles and removed his foot from the pedal. At the time he was removing a pressed drawer front from the die, his fingers were caught necessitating the amputation of the top joints of the 2nd and 3rd fingers of his left hand.

When the matter was investigated the inspector tried the operating mechanism and found that once the machine was started it would continue as long as the foot pedal was kept depressed even though the handles were released. He considers that the injured party probably released the handles but was tardy in moving his foot from the pedal keeping it there long enough to put another cycle into operation.

I think this emphasises that safety devices which are not positive in action lead to a sense of false security. For press work the fence type guard interlocked with the clutch mechanism seems to give the best protection.

Case F.

This accident concerns a pneumatic grinding wheel which was mounted on a bench. While running under no load the wheel burst, and flying to pieces, hit the victim causing injuries to the groin and abdomen.

When investigating this mishap the inspector checked the revolutions of the machine and found that they were more than double the permissible for the type and size of wheel used.

This accident is remarkable only for the frequency with which this type of accident happens, particularly with air driven grinders, where the speed can be varied so much and often is not regulated to the allowable wheel maximum. Too much emphasis cannot be placed on how critical it is to restrict the speed of all grinding wheels to that stipulated by the manufacturer.

Return No. 7.

"F" Denotes Fatal.

Showing Number of Serious Accidents, Both Fatal and Non-fatal which Occurred in Proclaimed Districts during the Year Ended, 31st December, 1963.

Industry	Circular Saw	Bandsaw	Buzzer (Planer)	Spindle Moulder (Shaper)	Belt Sander	Belts and Shafting	Gearing	Chaindrive	Hoist	Conveyer (Screw)	Elevator (Tray)	Rim Runner (Lifting Gear)	Mobile Crane	Abrasive Wheels	Polishing Buff	Lathe	Drilling Machine	Milling Machine	Wiredrawing and Processing	Press (metal)	Press (Other)	Printing Machine	Rolls	Coil Winding M/c	Teasing M/c	Woolcombing M/c	Wool Press	Mincer	Air Line (Clearing Pig)	Totals per Industry
Woodworking and Furniture	3	1	1	2	1	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	8
Metalworking and Engineering	....	....	....	....	....	....	....	....	....	....	....	....	1	2	....	1	2	1	7	3	....	....	....	1	....	....	....	....	....	18
Printing and Allied Industries	1	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	1	1	....	....	....	....	....	....	3
Food and Drink Processing	1	1	....	....	....	1	1	1	....	....	1	....	....	....	....	....	....	....	....	....	....	....	1	....	....	....	....	1	....	8
Building Materials and Building	....	....	....	....	....	....	....	....	1	....	....	1F	3	....	....	....	....	....	....	....	....	....	....	....	1	....	....	....	....	6 (1F)
Mining	2	....	....	....	....	....	....	....	....	....	....	....	....	1	....	....	1	....	....	....	....	....	....	....	....	....	....	....	....	4
Wool Processing	....	....	....	....	....	....	....	1	....	....	....	....	....	....	1	....	....	....	....	....	....	....	....	....	....	1	1	....	....	4
Other	1	....	2	....	....	....	1	....	....	1	....	....	1	....	....	....	....	....	....	....	1	....	1	....	....	....	....	....	1	9
Totals per Type of Machine	8	2	3	2	1	1	2	2	1	1	1	1F	5	3	1	1	3	1	7	3	1	1	3	1	1	1	1	1	1	60(1F

Return No. 7a.

Showing Number of Accidents not Classed as Serious under the Act and not Included in Return No. 7 but were Reported and Investigated During the Year Ended 31st December, 1963.

Industry	Spindle Moulder (Shaper)	Wood Boring	Belts and Shafting	Mobile Crane	Wiredrawing and Processing	Press (metal)	Abrasive Wheels	Drilling M/c	Rolls	Teasing M/c	Beaters	Escalator	Winding Engine	Autoclave	Totals per Industry
Woodworking and Furniture	1	1	1	....	....	....	....	....	....	....	....	....	....	....	3
Metalworking and Engineering	....	....	....	1	6	1	....	1	....	....	....	....	....	....	9
Building Materials and Building	....	....	....	....	1	....	....	....	....	....	....	....	....	1	2
Mining	....	....	....	....	....	....	1	....	....	....	....	....	1	....	2
Wool Processing	....	....	....	....	....	....	....	....	....	1	1	....	....	....	2
Other	....	....	1	....	....	....	....	....	1	....	....	1	....	....	3
Totals per Type of Machine	1	1	2	1	7	1	1	1	1	1	1	1	1	1	21

Return No. 7b.

Accidents Involving Machinery not Subject to the Provision of the Inspection of Machinery Act, Reported to and Investigated by the Department in Compliance with Section 50 of the Act During the Year Ended 31st December, 1963.

Industry	Guillotine	Gearing	Abrasive Wheel	Circular Saw	Total Per Industry
Metalworking and Engineering	1	....	....	....	1
Food and Drink Processing	....	1	....	....	1
Mining	....	....	1	....	1
Agriculture	....	....	....	1(F)	1(F)
Totals per Type of Machine	1	1	1	1	4

Section 6.

EXAMINATION OF ENGINE DRIVERS, CRANE DRIVERS AND BOILER ATTENDANTS.

The Board of Examiners granted 84 Engine Drivers', 250 Crane Drivers' and 91 Boiler Attendants' Certificates during the year.

Compared with the previous year these figures show a decrease of 3, increase of 22 and increase of 12 respectively in the number of certificates granted.

Section 7.

AMENDMENTS TO ACT.

There were no amendments.

Section 8.

STAFF.

The inspectorial staff was brought up to allowable strength in April, 1963, with the filling of the vacant item left by the transfer of Inspector McAllister late in 1962, and the new item created.

Unfortunately, my prediction in the last report that even at full allowable strength the present staff could not cope with the amount of work to be done and the forseeable proved correct.

Design drawings for checking and approval maintained the level set in 1962 which showed an increase of approximately 70% on 1961 figures. The number of cranes registered showed an increase of 30%. Pressure vessels registered increased by 4%, and machinery by 5%. In addition this year has seen the introduction of crane testing facilities at the Mines Department, Welshpool area. Quite a number of cranes were tested involving an Inspector's time over long periods.

The number of lifts has increased by approximately 3%.

The foregoing increases would have nullified the increase in inspection staff still leaving a large number of inspections which we were unable to do.

Towards the end of the year a further vacancy was created by the transfer for Mr. Cameron to the Country Towns Water Supply Branch of the P.W.D.

Clerical staff numbers have remained static but one assistant position was re-classified from female to male clerk. With the transfer of one female assistant to the Police Department, this position was filled by a male clerk.

Both the Inspectorial and Clerical Sections have again given their whole hearted co-operation and responded willingly to heavy demands often made upon them.

I would like to thank all staff members for their loyal and unstinting service during the year.

To the Police Department, appreciation for continued co-operation by its officers in the reporting and investigation of accidents in which we were associated.

In conclusion on behalf of all staff members and myself I wish to express appreciation of the ready 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. 9.

Revenue and Expenditure for year ended 31st December, 1963, and comparison with preceding year.

——	Revenue	
	1963	1962
	£ s. d.	£ s. d.
Fees from Boiler Inspections	5,900 16 9	5,886 1 3
Fees from Machinery Inspections	10,464 0 5	9,229 2 4
Fees from Engine Drivers	860 5 0	788 4 3
Incidentals	234 2 10	223 11 1
Total	£17,459 5 0	£16,126 18 11

Increase in Revenue compared with 1962—£1,332 6s. 1d.

——	Expenditure	
	1963	1962
	£ s. d.	£ s. d.
Salaries	40,569 17 3	31,761 14 1
Incidentals	9,552 0 8	6,433 8 6
Engine Drivers' Examinations	145 1 7	402 19 7
Totals	£50,266 19 6	£38,598 2 4

Increase in Expenditure compared with 1962—£11,688 17s. 2d.

Return No. 10.

Showing Distances Travelled, Number Inspections Made and average Miles Travelled for Inspections for the year ended 31st December, 1963.

——	Road Miles	Air Miles	Rail Miles	Water Miles	Collective Mileage all Transport Services	Number of Inspections	Average Miles per Inspection
Districts operated from Perth	110,330	1,000	*Nil*	*Nil*	111,330	36,142	3·08
Comparison with 1962	Inc. 12,216	Inc. 800	*Nil*	*Nil*	Inc. 13,016	Inc. 4,203	Dec. 0·67
Districts operated from Boulder	14,631	....	....	....	14,631	3,811	3·84
Comparison with 1962	Inc. 2,442	....	....	....	Inc. 2,442	Dec. 871	Inc. 1·24
Totals	154,961	1,000	*Nil*	*Nil*	125,961	39,953	....
Comparison with 1962	Inc. 14,658	Inc. 800	*Nil*	*Nil*	Inc. 15,458	Inc. 3,332	3·15

Note Abbreviations :—Inc. = Increase ; Dec. = Decrease.
Average Miles per inspection all districts, 1963 .... 3·15
Average Miles per inspection all districts, 1962 .... 3·01
Increase per inspection compared with 1962 .... Dec. 0·14

DIVISION VII

Government Chemical Laboratories Annual Report—1963

I have the honour to present to the Hon. Minister for Mines a summarised Annual Report on the operations of the Government Chemical Laboratories for the year ended 31st December, 1963.

Administration

The Laboratories consist of 6 Divisions, a Physics and Pyrometry Section, a central office and a library 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. Inst. F., F.R.A.C.I., F.R.I.C.

Agriculture and Water Supply Division—R. C. Gorman, B.Sc., A.R.A.C.I., M.A.I.A.S., Divisional Chief.

Engineering Chemistry Division—S. Uusna, Dr. Ing., A.M.I.E. (Aust.), M. Inst. F., Divisional Chief.

Foods, Drugs, Toxicology and Industrial Hygiene Division—N. R. Houghton, B.Sc., A.R.A.C.I., Divisional Chief.

Fuel Technology Division—R. P. Donnelly, M.A., B. Sc., M.I. Gas Eng., 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.P.I., Divisional Chief.

Mineralogy, Mineral Technology and Geochemical 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., Physicist and Pyrometry Officer.

Librarian—Miss J. E. Maughan, B.A.

Office—Miss D. E. Henderson, Senior Clerk.

At 31st December, 1963, the staff numbered 80, being—

Professional	48
General	19
Clerical	8
Wages	5

For the first time in years 1963 was not a difficult year for staff either professional or general or clerical. This was so for professional and general staff only because the slow construction of extensions to the Laboratories has resulted in two of our laboratories being unusable for all of the year. In addition to the above staff we have vacancies for six professional and two general staff, but have not at present the physical space to accommodate the personnel. The majority of these vacancies are positions created in anticipation of the slight increase in laboratory space resulting from the current building extensions.

The close association of these Laboratories with other Government Departments and with kindred associations was maintained during 1963 and various members of the staff are members of the following Committees—

Air Pollution Committee.

C.S.I.R.O. State Committee.

Foods and Drugs Advisory Committee.

National Association of Testing Authorities, State Committee.

Oils Committee of the Government Tender Board.

Paints Advisory Committee of the Government Tender Board.

Pesticides Registration Committee.

Phytochemical and Toxic Plants Committee.

Rivers and Waters Technical Advisory Committee.

Swan River Conservation Board.

Veterinary Medicines Advisory Committee.

Water Purity Advisory Committee.

Most of these Committees meet regularly and are very active and occupy considerable time of the officers concerned, not only for the meetings, but also for inspections, preparation of material and analyses of samples. This has been particularly so for 1. the Air Pollution Committee for which, in addition to our observational and survey work, we prepared a draft report and 2. the Swan River Conservation Board which requires considerable time and thought and for which a large number of analyses are made (144 samples) in connection with possible pollution of the Swan River. The Pesticides Registration Committee dealt with 153 applications for registration of new pesticide formulations. The total number of applications received by this Committee to 31st December, 1963, is 1,519. A matter of great concern to this Committee is the poisonous nature of most of the newer pesticides, particularly as many of them can be absorbed through the skin. The Veterinary Medicines Advisory Committee dealt with 848 applications for registration. Of these 675 were re-registrations and of the remaining 173, 122 were new registrations, 14 were a change of formula or claims, 8 were deferred, 19 did not require registration and 10 were rejected.

Equipment

Major items of equipment added to our facilities in 1963 include (1) a British Refractories Association refractoriness under load furnace (2) a Pyrometric Cone Equivalent furnace (3) a Lovibond Tintometer and accessories for the measurement of surface colour (4) a Hurricane air sampler for work on air pollution (5) a Gas Chromatograph for the determination of very small quantities of substances, especially of pesticide residues on and in food, (6) a 4 stage curved plate electrostatic separator with pneumatic conveyor-heater (7) a 3 disc electromagnetic separator.

Accommodation

Although it is pleasing to record that building extensions to these Laboratories are in progress it is disappointing that the construction of Stage 1 is extremely slow—being several times as long as was anticipated. As a result, two of our laboratories have been out of commission for all of 1963, and we have been working under all the disabilities inseparable from building operations. At the end of the year it was not possible to forecast when Stage 1 would be completed but nevertheless the planning of Stage 2 was well advanced. Stage 2 will approximately double our actual laboratory facilities and it is hoped that this stage will be completed more expeditiously than Stage 1. It is now (31st December, 1963) nearly 5 years since my first formal request for additional accommodation. Until this is provided these laboratories will not be able to give the service it can and should give to other Government Departments, the public and the State. Because of increasing complexity in the work required, increasing specialisation and increasing cost of equipment and facilities, no other laboratory in the State is capable of undertaking even a small portion of the wide field which these laboratories cover.

General

The total number of registrations in 1963 was 3,532, a reduction of nearly 7 per cent. compared with 1962 (3,793) but the number of samples received in 1963 was 11,421, an increase of some 7 per cent. over the number received in 1962 (10,658). Because of this and the unavailability of two of our laboratories the "samples in hand" (samples received but not reported) at the end of the year, 1707, were nearly twice the samples in hand at the beginning of the year, 880.

The number of registrations and of samples does give some measure of our activities but does not completely describe our work. A major factor in this is the enormous variation in the amount of work associated with different samples but also it is not possible to give a statistical account of the time and effort devoted to the various Committees previously mentioned; to advisory work for Government Departments, to industrial firms and to the general public; attendance at Courts and visits to factories and so on.

In previous Annual Reports I have referred to the large number of State Government Departments which consulted us for assistance and advice, as exemplified by the receipt of samples from them, and thus these Laboratories exert a marked influence on Government expenditure. In my Annual Report for 1961 I included a Table showing the State Government Departments for which our individual Divisions did work; 1963 showed a similar pattern, samples were received from 16 of the 28 Government Departments shown in the Public Service List for 1963. The assistance given ranged from the determination of a few parts of selenium in 100,000,000 parts of pasture in connection with white muscle disease of sheep to handling tons of material for advice to industry.

For such a wide range of activities we need a very broad library and in 1963 there were 2,303 accessions to our library. In addition to reading in the library there were 1,916 loans from the library to staff members and 296 inter-library loans. This latter facility is of great value since it enables us to reduce the number of Journals to which we subscribe and for which we would consequently have to find space.

Since we are the focal point for so many Government Departments it is not uncommon for us to be in the position of co-ordinator of Departments, e.g. air pollution problems may come to us from one or more of four Departments, water supplies to country towns may come to us from three Government Departments—as well as from Local Authorities or private persons.

The samples received were allocated to the various Divisions of the Laboratories according to the specialised work undertaken by each Division, see Table 1. In a number of cases sample(s) were allocated to more than one Division because for the full elucidation of the problem it was necessary to call on the experience and abilities of different specialists. Such samples are not usually registered twice but do show in the totals of samples received by the Divisions so the total shown in Table 1 is greater than the total of samples quoted earlier in this report.

Major examples of this co-ordination are—

(1) The X-ray examination by the Physicist of samples which were also examined in (a) the Agriculture and Water Supply Division or (b) the Mineral Division.

(2) Air pollution samples examined in the Fuel Technology Division and also in the Mineral Division.

(3) Bloating shales and clays for which the Fuel Technology Division did the main work but there were contributions also from the Mineral Division and the Engineering Chemistry Division.

(4) Analyses by the Mineral Division and the Fuel Technology Division for control and evaluation of work done in the Engineering Chemistry Division (upgrading ilmenite, beneficiation of lime sand).

(5) Clays for brick making, Mineral Division and Fuel Technology Division.

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 as separate entities. Discussion and interchange of ideas between Divisions is encouraged since the problems received by one Division may be helped by, indeed may rely on, the specialists in another Division. This co-operation and inter-Divisional assistance is further support of the value of one centralised chemical laboratory able to call on the specialists in many fields instead of chemical sections in various Government Departments. As mentioned under Accommodation, these Laboratories are unique in the State and in the Commonwealth in the breadth of work we cover.

TABLE I.

Source and Allocation of Samples Received During 1963.

Source	Division						Total
	Agriculture	Engineering Chemistry	Food and Drug	Fuel Technology	Industrial Chemistry	Mineralogy	
Free :							
Agriculture Department	3,322	....	802	....	2	25	4,151
Departmental	25	3	4	71	....	241	344
Geological Survey Branch	313	....	....	....	....	229	542
Industrial Development Department	....	....	....	8	....	18	26
Labour Department	....	....	5	22	....	16	43
Local Government Department	....	....	....	103	....	100	203
Mines Department	17	....	48	....	....	27	92
Native Welfare Department	....	....	....	....	....	10	10
Police Department	12	....	1,153	2	....	14	1,181
Public	11	6	5	1	....	837	860
Public Health Department	31	....	262	1	1	23	318
State Batteries Branch	1	....	....	....	....	165	166
Swan River Conservation Board	....	....	145	....	....	....	145
Tender Board	....	....	93	....	....	....	93
University of W.A.	40	....	....	....	....	....	40
Other Government Departments	12	....	1	....	4	5	22
Pay :							
Civil Aviation Department	12	....	....	....	....	1	13
Commonwealth Departments	3	....	26	....	....	2	31
Hospitals	1	....	83	....	....	....	84
Main Roads Department	....	....	....	....	3	2	5
Metropolitan Water Suppply, Sewerage & Drainage Department	202	....	....	....	11	1	214
Milk Board	....	....	376	....	....	....	376
Public	837	....	192	126	52	744	1,951
Public Works Department	326	....	74	11	90	38	539
State Housing Commission	....	....	....	8	....	2	10
United States Navy	....	12	6	....	....	178	196
Other	....	....	4	....	....	....	4
	5,165	21	3,279	353	163	2,678	11,659

Fees were charged for work undertaken for some State Government Departments, for Commonwealth Government Departments, Hospitals, Milk Board, private firms and the general public but the greater part of our work is done free for other 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 1963 with 1962 there were some marked alterations in the numbers of various types of samples received. These were

	1962	1963
Marked Increase—		
Air pollution	—	111
Animal tissue	262	546
Clover	204	550
Corrosion	—	178
Dusts	44	146
Hay	16	76
Silage	109	207
Tobacco	162	581
Marked Decrease—		
Animal toxicology	87	48
Fertilisers	110	61
Industrial hygiene	446	233
Iron ore	451	254
Milk	574	382
Oats	57	14
Oil seeds	912	671
Oranges	80	—
Pasture	402	263
Wheat	329	75

L. W. SAMUEL,
Director.

AGRICULTURE AND WATER SUPPLY DIVISION

The physical and chemical examination of a very wide variety of materials for the Department of Agriculture and the examination of waters and problems related to water supply, water treatment and water potability, for the Public Works Department, the Metropolitan Water Supply Department and the general public has again been the main function of this Division.

The number of samples received in 1963 represents an increase of over 8 per cent. on 1962. 580 samples of tobacco from the last major tobacco trials of the Department of Agriculture were the main cause of the increase. There were also many changes in the numbers of other samples received. There were large increases in clover and animal liver samples and a correspondingly large decrease in others such as wheat plants and oil seeds. One important aspect of the work that has increased is the number of interviews and telephone inquiries in relation to water treatment and corrosion from Government Departments, private industry and individuals.

It has been a considerable inconvenience and a disappointment not to have completed the first stage of the building extensions, which were commenced in October 1962. The inconvenience caused by the delay in building alteration contributed to the large number of samples on hand, waiting examination. The current commencement of the second stage of building extension which will increase actual laboratory space is most welcome.

Details of the Division work for 1963 are included under the appropriate headings below. The types, sources and number of samples received are listed in Table 2 below.

TABLE 2.

Agriculture and Water Supply Division.

——	Agriculture Department	Departmental	Department of Civil Aviation	Metropolitan Water Supply	Mines Department	Police Department	Public Free	Public Health Department	Public Pay	Public Works Department	University of Western Australia	Other	Total
Animal—													
Blood	38	....	....	....	....	....	....	....	....	....	....	....	38
Blood sera	44	....	....	....	....	....	....	....	....	....	....	....	44
Bone	21	....	....	....	....	....	....	....	....	....	....	....	21
Bovine hair	40	....	....	....	....	....	....	....	....	....	....	....	40
Calculi	14	....	....	....	....	....	....	....	....	....	....	....	14
Kidney	14	....	....	....	....	....	....	....	....	....	....	....	14
Liver	310	....	....	....	....	....	1	....	....	....	....	....	311
Sheep uteri	10	....	....	....	....	....	....	....	....	....	....	....	10
Urine	32	....	....	....	....	....	....	....	....	....	....	....	32
Wool	9	....	....	....	....	....	....	....	....	....	....	....	9
Other	13	....	....	....	....	....	....	....	....	....	....	....	13
Cereal—													
Oat—													
grain	1	....	....	....	....	....	....	....	....	....	....	....	1
plants	13	....	....	....	....	....	....	....	....	....	....	....	13
Wheat—													
chaff	1	....	....	....	....	....	....	....	....	....	....	....	1
flour	3	....	....	....	....	....	....	....	8	....	....	....	11
grain	14	....	....	....	....	....	....	....	....	....	....	....	14
leaves	39	....	....	....	....	....	....	....	....	....	....	....	39
Other	10	....	....	....	....	....	....	....	....	....	....	....	10
Fertiliser—													
Fertiliser	34	....	....	....	....	....	....	....	3	....	....	....	37
Limes	1	....	....	....	....	....	....	....	8	....	....	....	9
Other	12	....	....	....	....	....	....	....	3	....	....	....	15
Horticulture—													
Apple leaves	41	....	....	....	....	....	....	....	....	....	....	....	41
Cauliflower leaves	39	....	....	....	....	....	....	....	....	....	....	....	39
Celery	16	....	....	....	....	....	....	....	....	....	....	....	16
Citrus leaves	21	....	....	....	....	....	....	....	....	....	....	....	21
Tobacco	581	....	....	....	....	....	....	....	....	....	....	....	581
Other	27	....	....	....	....	....	....	....	....	....	....	....	27
Miscellaneous—													
Deposits	....	....	....	8	....	....	....	....	1	16	....	1	26
Linseeds	282	....	....	....	....	....	....	....	....	....	....	....	282
Safflower	47	....	....	....	....	....	....	....	....	....	....	....	47
Other	2	13	....	....	8	12	....	2	23	12	....	4	76
Pasture and Fodder—													
Clover	510	....	....	....	....	....	....	....	....	....	40	....	550
Grass	22	....	....	....	....	....	....	....	....	....	....	....	22
Hay	76	....	....	....	....	....	....	....	....	....	....	....	76
Lucerne	26	....	....	....	....	....	....	....	2	....	....	....	28
Lupins	118	....	....	....	....	....	....	....	....	....	....	....	118
Pasture	262	....	....	....	....	....	....	....	1	....	....	....	263
Silage	206	....	....	....	....	....	....	....	1	....	....	....	207
Sorghum	15	....	....	....	....	....	....	....	....	....	....	....	15
Stock Foods	23	....	....	....	....	....	....	....	2	....	....	....	25
Feeding Stuffs Act	10	....	....	....	....	....	....	....	....	....	....	....	10
Sudan Grass	10	....	....	....	....	....	....	....	....	....	....	....	10
Other	42	....	....	....	....	....	....	....	3	....	....	....	45
Soils	214	....	12	....	....	....	....	....	17	....	....	....	243
Water	61	12	....	194	323	....	10	29	765	298	....	9	1,701
	3,324	25	12	202	331	12	11	31	837	326	40	14	5,165

Soils

1. Copper in soils. Investigations were carried out into the determination of "available" copper in soils using the 0.05M E.D.T.A. extraction method of Mitchell, Reith and Johnson "Plant Analysis and Fertiliser Problems" I.R.H.O. Paris 1957.

(a) Esperance Downs Research Station.—24 sandy soils from a Department of Agriculture experiment on land cleared in 1951 and fertilised with four treatments of super, super plus zinc, super plus copper and super plus copper plus zinc and sown to wheat, oats and barley were analysed for "available" copper. After the first cropping these soils were sown to sub-clover till they were cropped to wheat, oats and barley in 1957 and again in 1962. These soils had received no further dressing of copper since the 1951 initial treatment. Total copper was also determined on these soils. The results in Table 3 show the yield responses of each cereal to the initial copper dressing, over the 3 years of cropping. The replicate results for 0.05M E.D.T.A. soluble copper show that, with the exception of two soils, this method can differentiate between soils which have and have not had added copper. Soils having of the order of 0.2 p.p.m. of copper are those that have had added copper. This figure is quite low, Mitchell et al quote soils having less than 1 p.p.m. of "available" copper as being deficient. The total copper replicate figures show the variability of total copper in these soils and the lack of any relationship with yield or treatment.

TABLE 3.

Copper in Soils.

Treatment	Yield			Copper, Cu. parts per million			
	1951	1957	1962	Total		0.05M EDTA Soluble	
				Rep. A	Rep. B	Rep. A	Rep. B
	bushels/acre	bushels/acre	bushels/acre				
Oats							
Super	1·1	15·6	65·2	6·4	16·2	0·18	0·09
Super + zinc	1·1	15·2	62·5	4·1	2·5	0·20	0·13
Super + copper	2·3	16·8	70·0	5·2	4·0	0·20	0·21
Super + zinc + copper	5·2	21·2	65·5	6·8	2·5	0·20	0·19
Wheat							
Super	1·7	6·5	*	6·3	4·1	0·11	0·05
Super + zinc	0·1	0·6	*	7·5	3·2	0·11	0·09
Super + copper	4·9	8·2	*	4·8	3·2	0·20	0·20
Super + zinc + copper	5·1	8·9	*	5·9	3·4	0·23	0·20
Barley							
Super	1·3	16·2	26·5	5·0	4·8	0·10	0·06
Super + zinc	0·5	11·6	24·4	6·0	4·0	0·08	0·07
Super + copper	3·6	18·5	36·0	3·3	4·2	0·23	0·16
Super + zinc + copper	3·8	17·6	38·6	4·5	4·2	0·18	0·19

* No yield because of rust.

"Available" and total copper determinations were made on another series of soils from the Research Station. These were from a copper residual trial on Caitup gravelly sand. These soils had had the equivalent of 5 lbs. per acre of copper sulphate applied in 1951 and again in 1958 and after sampling, copper was to be applied again this year, before being sown to cereals. Variability of soil copper was tested by taking five samples per plot and analysing each separately. Each sample consisted of a 1½ in. core of the surface 4 in. at one chain intervals. The 0.05M E.D.T.A. soluble coppers all varied considerably within each plot and the levels were much higher than the previous sandy soils above. These levels range from 0.30-6.0 p.p.m. in view of which a yield response to copper this year would be unlikely. 1963 yields are not yet available for confirmation of this.

(b) Woogenellup.—8 gravelly sandy loams from Woogenellup known to be copper deficient were analysed for total and 0.05M E.D.T.A. soluble copper. 4 of the soils had no treatment and the other 4 had 9 lbs. per acre of copper sulphate applied over several years. The average of treated and non-treated soils are given below.

Treatment	Copper, Cu parts per million Total	E.D.T.A. Soluble
Nil	12.6	0.08
9 lb. copper sulphate/acre	6.6	1.1

2. From the irrigation areas at the Ord River diversion dam, 10 samples of Kununurra clay soils were analysed for pH, cation exchange capacity and exchangeable sodium percentage. These clays all had high cation exchange capacity of 38-50 milliequivalent per 100 grams due to the presence of montmorillonitic clay. Exchangeable sodium percentages of 12-25 were found in 8 of these soils. These exchangeable sodium percentages are high enough to cause future irrigation problems, through poor permeability.

3. A further 38 soils from the long term Ley Rotation Experiment at Wongan Hills, mentioned in the 1962 Annual Report, were analysed for nitrogen from this investigation into the build up of soil nitrogen.

4. From a Department of Agriculture soil survey at Perillup 23 samples of soils from several profiles were analysed in detail, to provide fundamental information about the soils of this district.

5. As in previous years a number of soils were examined for farmers, home and market gardeners, for pH and total salts to try to find the cause of poor growth.

Water and Water Treatment

The examination of water from all parts of the State for determination of their suitability for domestic, industrial or agricultural use, for Government Departments, private industry and individual farmers and householders has again been the major part of this section of the Division's work. This year because of the expansion and consequent increased activity of the Hydrology Division of the Geological Survey there has been a considerable increase in samples requiring more detailed analyses. Over 300 samples from this source alone were received in 1963 compared with 55 in 1962. Much of the additional work for the Geological Survey has been in relation to possible town supplies, but a considerable number of detailed analyses have been required for fundamental examination of the waters by the graphical method of Schoeller (France Soc. Geol. Comptes Rend. Sommaire et Bull. Ser 5, V.5, p. 651-7). This graphical method of expressing the results of analysis as the logarithm of the equivalent parts per million of the major constituents, is one of several graphical methods for comparison of waters, to supply information about the aquifers in which the water occurs. None of these graphical methods has been universally accepted as being of any great value. Their main use is the simple graphical expression of results of water analysis. However variation in water quality due to many other factors besides geological, makes their use in interpreting differences in aquifers very difficult.

Of the 1,700 samples of waters and water problems examined the following are of more interest:—

(1) Northampton Water Supply.—Because of the relatively high salinity and the variable amounts of copper and lead in Northampton water supply, problems in the reticulation have been continuous since the establishment of the town supply. A relatively recent installation of a base-exchange softening plant to remove copper and lead and at the same time to soften the water, has not proved satisfactory. This plant, which was not installed on our advice, has had considerable corrosion problems due to the high level of copper in the water and has had a considerable reduction in capacity due to coating of the exchange resin with iron oxide from corrosion of pipes prior to the softener. The main problem subsequent to the installation of the softening plant has been due to discolouration of the town water supply, by corrosion of the mains by the corrosive softened water. This corrosiveness could not be reduced by the usual practice of bypassing some of the hard water because of the copper in the untreated water.

On our advice an up-flow clarifier was built to lime-soften the water, which we had found to also remove the copper and lead. A chemist from the Division spent a week in Northampton starting the treatment of the water. Unfortunately because of unavailability of a dry feeder, caustic soda had to be used instead of lime for treating the water. Because caustic soda added considerably to the alkalinity of the water, which would not happen with lime, softening of the water could not be carried out and only sufficient caustic soda and sodium aluminate were added to precipitate copper and render the water less corrosive in the reticulation. When a solid feeder becomes available the more satisfactory treatment of the water with lime will be possible.

(2) Donnybrook Water Supply.—An investigation of the proposal to install an iron removal plant on the Donnybrook water supply, was made on the site. Inspection and correct sampling of the two bores supplying the town showed that the problem of discoloured water in the town was not related to iron in the bore water as had been supposed previously because of incorrect sampling. The main cause of discolouration was found to be due to corrosion of the reticulation by the very corrosive bore waters. Both bores were found to contain only a small amount of iron in solution, 0.3 and 0.6 parts per million, enough to cause some trouble but not enough to cause the discolouration that was occurring. The main cause of corrosiveness of the bore waters was due to over 100 parts per million of free carbon dioxide in each water.

As the main from the bores to the town reservoir was used for both filling the reservoir and as part of the reticulation, aeration at the reservoir would only be partly successful. Temporary measures of injecting caustic soda to raise the pH to 8.4 were recommended and a permanent treatment by duplication of the main to the reservoir, then aeration of the water at the reservoir with the addition of lime if required, plus baffling of the reservoir to allow it to act as a horizontal clarifier for removing the small amount of precipitated iron, was also recommended.

(3) Iron in Water.—Additional investigations were made into the problem of removal of iron from water following on investigations previously reported in our 1961 Annual Report.

(a) The use of the additional sequestering or reducing agents at the rates below, were tried to keep the ferrous iron of ground water in solution, after exposure to air; tannic acid 1-20 ppm, calgon 1-20 ppm, trisodium phosphate 1-20 ppm, sodium sulphite 10-20 ppm, citric acid 10-40 ppm and oxalic acid 10-40 ppm. Of these, only citric acid added at 20-40 ppm prevented the occurrence of turbidity or the settling of a brown deposit, when water containing 5 ppm of ferrous iron was left exposed for 24 hours.

(b) The use of pyrolusite (manganese dioxide) as a catalytic filter was also investigated. Well aerated, ferruginous water after passing through a bed of 60 mesh pyrolusite at the rate of 200 gallons per square foot per hour was found to be free of iron. At rates of 400-600 gallons per square foot per hour about 80 per cent of the iron was removed. While this method of iron removal is promising, the removal of the filtered iron deposit from the pyrolusite by back washing proved to be very difficult.

(c) The continuous regeneration of manganese zeolite by adding sufficient potassium permanganate to the water to make it just pink prior to passing the water through a bed of manganese zeolite was also examined. This method, which overcomes the disadvantage of the low capacity of manganese zeolite for iron exchange was found to reduce 7 ppm of ferrous iron to less than 0.1 ppm when passed through the bed at the rate of 300 gallons per square foot per hour. Potassium permanganate had to be added at the rate of 1 ppm for every 1 ppm of iron. One disadvantage of this method was that up to 0.4 ppm of manganese was found in the eluate from the bed of zeolite.

(4) Detailed analysis of water from the Diversion Dam on the Ord River and from the Cunningham River, a tributary of the Fitzroy River, are of interest because of irrigation development at Kununurra on the Ord and the possibility of a future irrigation scheme on the Fitzroy. Results of these detailed analyses are given in Table 4.

TABLE 4.

Analyses of Ord and Fitzroy Rivers

———	Ord River	Fitzroy River (Cunningham River)
Specific Conductivity (micromhos at 20°C)	310	185
Turbidity (A.P.H.A. units)	less than 5	less than 5
Colour (Hazen scale)	20	less than 5
pH	7·8	7·6
	Parts per million	
Free carbon dioxide CO_2	4	5
Total alkalinity as $CaCO_3$	135	95
Mineral Matter—		
Calcium, Ca	32	22
Magnesium, Mg	8	7
Sodium, Na	30	7
Potassium, K	4	2
Bicarbonate, HCO_3	165	116
Carbonate, CO_3	*Nil*	*Nil*
Sulphate, SO_4	11	1
Nitrate, NO_3	less than 1	less than 1
Chloride, Cl	26	4
Iron, Fe	less than 0·1	less than 0·1
Boron, B	less than 0·1	less than 0·1
Total dissolved solids (by evaporation)	230	110

Both of these waters would vary in quality with seasonal conditions, but these results indicate that they would be excellent for irrigation.

(5) Thermal Stratification in Reservoirs.

(a) Mundaring Weir.—After an abnormally wet winter which caused the Weir to overflow, unusually high levels of colour of 40-50 Hazen units were found in the water. This increase in organic matter caused concern, as it was anticipated that it could cause a considerable oxygen depletion at depth, with consequentrial increase in iron and manganese and hydrogen sulphide production. Depth sampling in May, September and December indicated definite thermal stratification but the oxygen in the bottom (120 ft.) sample in December was only down to 2.2 ppm, showing that aerobic conditions still existed and abnormal iron and manganese levels were not obtained. December samples showed that the colour had decreased to 20 Hazen units, an acceptable level, without the anticipated oxygen depletion.

(b) Serpentine Dam.—Depth sampling at Serpentine Dam was carried out at approximately 2 monthly intervals during the year. Thermal stratification existed in the reservoir from January to June. In June, isothermal conditions existed and there was mixing to depth of the water. From September to December stratification occurred again with an epilimnion from 0-25 ft., a thermocline from 25-50 ft. and an iso-thermal hypolimnion below 50 ft. Dissolved oxygen levels were found to be almost zero below 50 ft., just prior to the winter overturn period. A distinct stratification of dissolved salts due to evaporation from the surface of the reservoir also closely paralleled the thermal stratification throughout the year.

The winter overturn in June caused an appreciable increase in iron, manganese and colour and a decrease in dissolved oxygen in the surface water. Surface absorption of oxygen and continuous mixing conditions over the next several weeks, produced satisfactory conditions again in the reservoir.

(6) Fluoride in Water.—Because of current interest in fluoridation of water supplies, additional information was sought on fluoride in water levels, from areas where optimum levels of fluoride exist naturally. The present United States Public Health Service recommendation for the level of fluorine in water for prevention of dental caries is now dependent on the average maximum daily air temperature. Depending on the temperature there are lower, optimum and upper control levels. For Perth these are 0.7, 0.8 and 1.0 ppm respectively. Hence if fluoridation of water supplies was introduced to Perth the recommended level should be 0.8 ppm and not the universally accepted 1.0 ppm.

In Onslow the optimum level would be 0.7 ppm fluoride. Recent analysis of the town supply showed it to have this level naturally. For Marble Bar the optimum is 0.7 ppm and recent analyses showed the supply to have 1.0 ppm. In Carnarvon with an optimum of 0.7 ppm, the town supply has averages of about 1.4 ppm since 1960, i.e. about twice the optimum. Prior to 1960 the Carnarvon town supply had approximately 0.5 ppm fluoride. In 1960 the source of the supply was changed from two wells to two bores, one of which has 2.0 ppm of fluoride and the other 0.8 ppm.

Fertilisers

1. Fertiliser Act.—Only 3 samples were received this year and as these were not received till the end of the year they will not be recorded till 1964.

2. 8 samples of liquid manure from a collection pit on Wokalup Research Station were analysed for their fertiliser value. They were found to contain 15-400 ppm nitrogen, 11-39 ppm phosphorus and 100-200 ppm potassium.

3. From an experiment on sand plains at Gutha, where the first reported response of wheat to molybdenum in this State had occurred, 14 samples of superphosphate with and without minor elements added, that had been used in the trial, were analysed for copper, zinc and molybdenum. Some of the copper and zinc treatments gave inconsistent increased grain yields and it was thought that this might be attributed to molybdenum impurities in the source of copper and zinc used. Analysis of the samples did not confirm this; all samples which had not had molybdenum added to them had only 1-2 ppm of molybdenum present.

4. 26 miscellaneous organic and mixed fertilisers were examined to assess their nutrient status in relation to proposed usage or reported responses.

Pastures, Fodders and Stock Foods

1. Feeding Stuffs Act.—Only 10 samples were taken by the Department of Agriculture Feeding Stuffs Inspector this year. This number, though to our advantage, is only a token examination of registered stock foods. Provided that regular inspection of manufacturers is made by the Inspector then the total numbers of samples taken for analysis is not necessarily of importance.

Of the 10 samples examined, all complied with their registered analysis, except for 4 samples which were slightly deficient in protein.

2. 121 samples of pasture were received for copper analysis from copper fertiliser trials and copper in pasture surveys from Bakers Hill, Bulyee, Katanning, Kellerberrin, Manjimup, Merredin, Midland, Moora, Narrogin, Wagin and Williams.

3. From a property at Boyup Brook where a peculiar thyroid condition in sheep associated with general ill thrift was being investigated, 3 samples of pasture were analysed for cobalt, copper, molybdenum and iodine. Iodine levels of 0.3-0.4 ppm were found in the samples.

4. The Australian Dairy Products Board Silage Competition was responsible for the majority of the 206 silage samples received for moisture and protein estimations.

5. From an investigation into a chronic scouring problem of beef cattle at Chittering, 6 samples of pasture were analysed for cobalt, copper, molybdenum and inorganic sulphate, as illthrift associated with possible high molybdenum and copper and inorganic sulphate interaction was thought to be a possible cause. This was not confirmed by analysis. The molybdenum levels of 0.37-0.67 ppm were much too low to be responsible.

6. Several arthrocnemum (samphire) species used to revegetate saline soils were examined for their protein, salt and oxalate contents. The oxalate was required as similar salino-philes, Kochia brevifolia, have been found to have high oxalate contents. These samples had 9.1-14.2 per cent. crude protein, 15.6-27.0 per cent. sodium chloride and 1.3-5.3 per cent. oxalate on dry basis.

7. 66 samples of pasture from time of closing after grazing and time of cutting experiments at Denmark, Wokalup, and Busselton were analysed for protein and fibre. The results confirmed Department of Agriculture opinion that in many of the dairying areas paddocks are closed for hay

too early. Later closing has produced equal and in some cases higher yields of hay plus the additional grazing time and also better quality hay.

8. From a property at Wooroloo, on which a dozen sheep had died from copper poisoning (one liver sample had 2300 ppm of copper) samples of pasture were analysed for copper, inorganic sulphate, molybdenum and lead. The results failed to implicate the pasture as the source of the copper either through high levels of copper or inorganic sulphate-molybdenum interaction.

9. Over 20 samples of Japanese millet, Sudan grass, sorghum almum, sorghum saccaline, and grain sorghum from Wiluna Ground Water Research Station were analysed for protein, fibre and phosphorus from a trial comparing production, protein content and hay quality of each species, when cut at various times during growth.

10. From urinary calculi trials, 18 samples of pasture being used in the trials were analysed for sodium, potassium, calcium, phosphorus, magnesium, cobalt and copper.

11. From lupinosis trials, 65 samples of pasture associated with lupins in the trials were analysed for nitrogen, cobalt, copper, molybdenum, inorganic sulphate, iron and vitamin E.

12. Selenium in pasture.

(a) Over 80 samples of pasture were analysed for selenium from diagnostic and survey samples. Wherever a sample of pasture had been taken from a property in connection with some disease other than White Muscle Disease, the Chief Veterinary Pathologist had requested selenium determination as well, to provide additional information on selenium levels in pasture throughout the State.

(b) Examination of selenium in pasture levels throughout the agricultural areas of the State, showed that the levels fitted into a pattern associated with the soil textures and mean annual rainfall of the areas.

In the 10-15 inch rainfall belt plant selenium contents were found to be all relatively high. Generally soils in this area are heavier in texture than in the higher rainfall areas. Even light soils in this area were found to grow pastures high in selenium but not as high as pasture grown on the heavy soils. The levels of pasture selenium in this rainfall belt were 0.05-0.62 ppm with an average of 0.26 ppm.

In the 16-20 inch rainfall belt the plant selenium ranged from 0.02-0.24 ppm with an average of 0.08 ppm. There was less obvious correlation with soil types in this area. Older land with a history of heavy superphosphate dressings generally produced lower plant selenium.

In the 21-30 inch rainfall belt, values ranged from 0.01-0.08 ppm with an average of 0.06 ppm.

In the 31-45 inch rainfall belt, values ranged from 0.02-0.06 ppm with an average of 0.03 ppm. All samples except one from this area were below the established level of 0.05 ppm selenium that has been associated with the appearance of clinical manifestations of White Muscle Disease.

13. Cobalt in Pastures.—Over 200 samples of miscellaneous pastures were analysed for cobalt from trials and diagnostic samples. As with selenium when pasture samples are taken from a property in relation to some other problem, cobalt analyses are also requested by the Chief Veterinary Pathologist to obtain information on cobalt levels in pasture throughout the State.

(a) The following average of five replicates for cobalt up take from a cobalt fertiliser trial at Esperance Downs Research Station were obtained, Table 5.

TABLE 5.

Cobalt in Pasture at Esperance Downs Research Station.

Treatment Applied in Autumn, 1962	Cobalt Co ppm. dry basis	
	1962 cut	1963 cut
Super	0·11	0·14
Super + 1 oz. per acre cobalt sulphate	0·10	0·15
Super + 3 oz. per acre cobalt sulphate	0·14	0·20
Super + 9 oz. per acre cobalt sulphate	0·31	0·26

These results show a definite cobalt residual in these soils in the second season after application.

(b) At Bramley Research Station a considerable loss or dilution of cobalt uptake was found in a fertiliser trial in the summer samples compared with spring samples, as shown in Table 6.

TABLE 6.

Cobalt in Pasture at Bramley Research Station.

Treatment	Cobalt Co ppm. dry basis	
	Spring Sample	Summer Sample
Super	0·05	0·02
Super + 1 oz. per acre of cobalt sulphate	0·07	less than 0·02
Super + 3 oz. per acre of cobalt sulphate	0·07	less than 0·02
Super + 9 oz. per acre of cobalt sulphate	0·12	0·02
Super + 18 oz. per acre of cobalt sulphate	....	0·03

(c) At Mayanup from a similar trial of 0, 1, 3 and 9 oz. per acre of applied cobalt sulphate, 0.09, 0.08, 0.17 and 0.18 ppm of cobalt respectively were found in the pasture. From a similar trial in which copper was applied to the control and to the 3 oz. per acre of cobalt sulphate treatment, an increase in uptake of cobalt as a consequence of the added copper was found.

14. A large number of miscellaneous pastures from all over the State were analysed for assessment of their feed value or their nutritional status with respect to animals or to explain poor pasture growth.

Cereals

1. Barley.—Two samples were received for analysis for protein, inorganic sulphate, cobalt, copper, molybdenum and selenium in connection with animal nutrition studies.

2. Maize.—Six samples of maize plants from fodder crop trials at Wiluna Groundwater Research Station were analysed for their feed value.

3. Oats—

(a) From urinary calculi trials six samples of oat plants were examined for calcium, magnesium, phosphorus, potassium, silicon, sodium, oxalate, cobalt, copper and selenium.

(b) From an effect on yield and quality trial on Avon oats by application of ammonium sulphate at Bramley Research Station, replicate samples were analysed for nitrogen. 1 cwt. per acre of ammonium sulphate applied 3 weeks after sowing, gave no increased uptake of nitrogen. 2 cwts. per acre increased nitrogen uptake from an average of 1.15 per cent. in the controls, to an average of 1.28 per cent.

(c) Samples of oat grain fed to pigs at Darkan were found to have only 0.01 ppm selenium. The pigs were showing chronic illthrift, which disappeared on the administration of selenium.

4. Wheat—

(a) The 1962-63 F.A.Q. wheat and flour milled from it were analysed as below:

——	F.A.Q., 1962–63	
	Wheat	Flour
	%	%
Moisture	9·6	11·9
Ash, at 13·5% moisture	1·28	0·47
Protein (Nx5·7) at 13·5% moisture	9·1	8·3
Maltose (Kent Jones)	....	3·35

(b) Duplicate bulked wheat leaf samples from a trace element trial at Esperance were analysed for manganese. Samples taken of the two youngest leaves, at about the 8-10 leaf stage of the plant, showed that the addition of manganese or copper, zinc and molybdenum together had no effect on manganese uptake but the addition of copper and zinc together slightly decreased manganese uptake.

(c) The possibility of nickel toxicity in two samples of wheat leaves from Southern Cross, showing bamboo striping symptoms, was not confirmed by spectrographic and chemical analysis of the leaves.

(d) 38 samples of Kondut wheat plants were analysed for manganese from Department of Agriculture cereal trials at Wandering, West Brookton and Boddington investigating the extent of manganese deficiency in this area and also the effects of ammonium sulphate and molybdenum application on manganese uptake. With added manganese additional manganese uptake was found when ammonium sulphate was applied as compared with equivalent amounts of urea. Because of very low levels of uptake of manganese even with added manganese, no effect of molybdenum application on manganese uptake was observed.

Plant Nutrition

1. Apples—

(a) 23 further samples of apple leaves were analysed for nitrogen, phosphorus and potassium in a Department of Agriculture survey of correlation between orchard fertiliser practice, soil type, and leaf content. Little correlation was found. The leaves were found to contain 1.94 per cent. nitrogen (range 1.73-2.70), 0.11 per cent. phosphorus (range 0.08-0.14) and 1.12 per cent. potassium (range 0.80-1.50).

(b) 5 samples of leaves from Stoneville Research Station were analysed for boron, copper, manganese, molybdenum and zinc from trees in which a complex nutritional problem had arisen. The results were inconclusive, but low levels of copper indicated that marginal copper deficiency may be involved.

(c) From a nutritional survey of south-west apple orchards, 35 samples of leaves were analysed for a range of nutrients.

2. Beetroot.—Samples of beetroot leaves from South Coogee which showed symptoms of suspected manganese deficiency, which had been controlled by fumigation treatment, when analysed for manganese were shown not to be deficient in this element.

3. Broad Beans.—2 affected plants, tops and roots, growing on an acid soil, pH 4.8, at Caversham and 2 healthy samples of roots and tops growing on the same soil which had been limed to pH 6.5, were analysed for aluminium, boron, calcium, copper, manganese, molybdenum, nitrogen, phosphorus, potassium and zinc, to find whether liming had increased the availability of any nutrient or decreased any possible toxicities. The main differences between the unhealthy and healthy plants, were the higher levels of manganese and zinc in the unhealthy plants but neither of these would be at levels considered to be toxic.

4. Carrots.—Samples of carrot leaves from a borax fertiliser trial sown on plots immediately after a beetroot crop, which had shown suspected boron deficiency symptoms, were analysed for boron. The results showed no significant uptake of boron and there was no response to the boron fertiliser.

5. Cauliflowers—

(a) Tip burn and stem rot in cauliflowers. This problem had previously been investigated by the Department of Agriculture, where the tip burn was thought to have been due to molybdenum deficiency and the stem rot to boron deficiency. Applications of molybdenum and boron fertilisers did not cure the trouble. In 1963 the trouble was more pronounced in metropolitan market gardens, during unusually hot and humid March weather. These climatic conditions combined with heavy applications of nitrogenous fertilisers, were thought to cause the trouble, due to too rapid uptake of nitrate with a consequential reduction in calcium uptake.

22 samples of cauliflower leaves were examined for calcium, chloride, molybdenum and nitrate contents. A large number of semi-quantitative tissue tests for nitrate were made on these samples, investigating the differences in nitrate levels within each part of fresh leaves of affected and unaffected plants.

No differentiation with respect to nitrate could be found between affected and unaffected plants but considerable variation between leaf parts was found, making the interpretation of tissue tests very difficult. Midribs were found to have the highest nitrate content, the nitrate generally decreasing along the midrib with distance from the base of the leaf. The veins of the leaf blades were next highest in nitrate and there was generally a decrease of nitrate along the vein with distance from the mid-rib. The leaf blades were the lowest in nitrate, having a slightly increased concentration in blade tissue nearest to the mid-rib or veins.

Chloride was found to be generally higher in the midribs than in the blades, and older leaves had considerably more chloride than young leaves. Calcium was generally higher in the blades than in the midribs and in both it increased with the age of the leaf. Molybdenum was also generally higher in the blades than in the mid-ribs, with little difference between young and mature leaves.

As all the crops had been harvested by the time our examinations were completed, further investigations into the problem this year were not possible. The indications are that trouble is caused by excess nutrient availability which is rapidly taken up by the plant during high photosynthesis activity at periods of high humidity, heat and light, which is then followed by periods of high heat and low humidity in which rapid transpiration causes concentration of the cell sap, with consequential cell damage. It is hoped in 1964, if the right weather conditions prevail, to check this theory by investigations into osmotic pressure and total electrolyte content of the cell sap.

(b) From a trial at Wanneroo, 8 samples of cauliflower leaves were analysed for molybdenum. These plants had shown the visual symptom of molybdenum deficiency, i.e. whiptail. Treated plants which had been sprayed with sodium molybdate showed no marked benefits, although they had absorbed considerable molybdenum. The untreated samples were shown to have about 2 ppm molybdenum, which is ample and would account for the lack of response in the treated samples.

(c) A number of other cauliflower leaves were analysed for confirmation of visual symptoms of nutrient deficiencies. One sample from York which showed manganese deficiency symptoms had an ample manganese content of 290 ppm. Boron analysis on this sample indicated a possible boron deficiency as it had only 13 ppm of boron. This was unexpected as a confirmed boron deficiency is as yet unknown in this State and the occurrence of boron deficiency on a loamy soil at York would not be anticipated. Similar symptoms in plants on sandy soils in the metropolitan area were found not to be due to boron deficiency as levels of 28-31 ppm of boron were found in these plants.

6. Celery.—16 samples of celery leaves from York, Osborne Park and Balcatta, where brown lesions and transverse cracking along ridges of the outsides of the stalks had occurred at random throughout the crop, were suspected of being boron deficient. Analysis was not conclusive for although some very low levels of boron were found (12-13 ppm) these also occurred in some of the healthy plants.

7. Citrus Leaves—

(a) 14 miscellaneous citrus leaves from a nutritional survey and from suspected deficient trees, were analysed for copper, magnesium, nitrogen, phosphorus, potassium and zinc.

(b) Examination of three samples of lemon tree leaves from Gosnells, in which nitrate accumulation in relation to molybdenum nutrition was suspected, showed no differences in molybdenum and nitrate levels between affected and healthy leaves. No differences were found in the magnesium or potassium levels, which were also suspected of being contributory.

(c) 4 samples of citrus leaves from the Gascoyne Research Station, which were showing yellow mottling indicative of minor element deficiency, were analysed for boron, copper, manganese and zinc. Unusually high levels of boron of 150-180 ppm were obtained in these samples although no boron had been applied to the soils. The zinc levels of 9-10 ppm in these and other healthy citrus trees indicate a low level of requirement for zinc by citrus trees.

8. Clover—

(a) 113 samples of clover from Baker's Hill, Bulyee, Katanning, Kellerberrin, Manjimup, Merredin, Midland, Moora, Narrogin, Wagin and Williams were analysed for copper in a copper in clover survey of the Department of Agriculture, from areas of known copper fertiliser history.

(b) 46 samples of different varieties of clover from Williams and Muradup were analysed for protein to assess the quality of feed available to stock over the summer months. At Williams the quality of Dwalganup variety was much poorer than Yarloop, Baccus Marsh, Woogenellup or Mt. Barker varieties. The yield of Dwalganup was also only about half of that of the other varieties.

(c) 40 samples of clover plant parts from 10 varieties of clover were analysed for cobalt to find any varietal or plant part variation in cobalt uptake. Unusually high cobalts of 1.0 and 0.83 ppm were found in the stem, leaf and petiole portion of Dwalganup and Mt. Barker varieties respectively.

(d) From a shallow sandy soil over granite at North Dinninup samples of clover from a suspected sulphur deficient and healthy area were analysed for total protein and nitrate nitrogen, phosphorus and sulphur. The deficient plants had an average of 0.08 per cent. sulphur, compared with 0.18 per cent. in the healthy plants. The other significant difference between healthy and suspected sulphur deficient samples, was an average of 3.37 per cent. protein nitrogen in the healthy samples and 1.77 per cent. in the suspected sulphur deficient samples.

(e) Suspected zinc deficiency in samples of clover from Badgingarra Research Station was not confirmed by analysis. These plants were from sandy soil which had had zinc applied in the first year of development yet in the second year showed acute zinc deficiency symptoms. High levels of zinc were found in all plots and adequate levels of phosphorus were also found. Phosphorus deficiency symptoms can sometimes be confused with zinc deficiency symptoms.

(f) From Esperance Downs Research Station and from a farmer's property at Yornup 195 samples of clover were analysed for zinc from a series of zinc fertiliser trials as below.

(i) In an experiment at each site, in 1959, each original plot was divided into halves so that one half was top dressed with zinc free phosphate (aerophos plus gypsum) and the other with superphosphate. This was maintained for each subsequent annual top dressing. The results below, Table 7, show, for samples taken in 1963, the average of zinc uptake with each phosphate source plus the zinc oxide treatments applied in 1959.

TABLE 7.

Zinc in Clover.

Treatment Zinc oxide lb./acre	Zinc, Zn ppm. dry basis			
	Esperance		Yornup	
	Aerophos	Super.	Aerophos	Super.
0	24	41	28	24
½	31	41	27	28
1	38	40	27	28
2	52	48	31	38
4	50	61	29	38
8	78	88	49	53
16	87	84	71	60

These results show that at the Esperance site, at the 0 and ½ lbs. per acre level of added zinc oxide the superphosphate is supplying a large percentage of the zinc in the plants, whereas at Yornup there is little difference between the zinc supplying power of the two sources of phosphorus. Also at Yornup there is very little residual effect of added zinc at the low levels of treatment.

(ii) From a residual zinc trial at Yornup also comparing the two sources of phosphorus the following averages of zinc uptake with treatment were found, Table 8.

TABLE 8.

Zinc in Clover at Yornup.

Treatment Phosphorus	Zinc oxide lb./acre	Zinc, Zn ppm. dry basis
Super	0	21
Aerophos	0	18
Super	2 every 3 years	26
Aerophos	2 every 6 years	25
Super	2 every 9 years	24
Super	2 every 9 years and again when required	31
Super	4 every 3 years	29
Aerophos	4 every 6 years	28
Super	4 every 9 years	33
Super	4 every 9 years and again when required	28
Super	4 in 1957, 1959 and 1966	20

(iii) 55 samples of clover were analysed for zinc from a residual zinc fertiliser trial at Esperance Downs Research Station. In this experiment the soil was virgin in 1952 and had had 180 lbs. per acre of superphosphate applied each year since, with the additional zinc oxide treatment given below with the averages of zinc uptake. These results show that there is no necessity for zinc fertiliser for clover on this soil, receiving this type of superphosphate treatment, Table 9.

TABLE 9.

Zinc in Clover at Esperance.

Treatment 180 lb. super every year plus zinc oxide lb./acre	Zinc, Zn ppm. dry basis
0	48
2 applied in 1953, 56 and 59	73
2 applied in 1953 and 56	68
2 applied in 1953	53
4 applied in 1953, 56 and 59	79
4 applied in 1953 and 56	68
4 applied in 1953	70
2 applied in 1953, 55, 58 and 61	81
4 applied in 1953, 55, 58 and 61	79

(g) From two glass house trials at South Perth, 102 samples of clover leaf and petiole samples were analysed for phosphorus. The first trial was on two different soil types, a gravelly sand from Boddington and a yellow sand from Esperance, comparing six rates of superphosphate application applied as a top dressing in February. The results of average of replicate phosphorus uptakes are given below, Table 10.

TABLE 10.

Phosphorus in Clover Glass House Trials.

Treatment Super lb./acre	Phosphorus P per cent, dry basis	
	Boddington Gravelly Sand	Esperance Yellow Sand
0	0·08	0·07
150	0·11	0·14
300	0·12	0·21
450	0·14	0·28
600	0·15	0·38
750	0·15	0·50

In the second Department of Agriculture glass house trial designed to find the effect of summer rain and time of top dressing on phosphorus uptake on Boddington gravelly sand, the treatments consisted of two rates of superphosphate 300 and 600 lbs. per acre and two times of top dressing, February and April and one time of watering, in February, equivalent to summer rain. The averages of three replicates showed no significant difference in phosphorus uptake.

9. Lucerne.—28 samples of lucerne were analysed for nitrogen in an investigation into the ability of different varieties and different rhizobium bacterial strains to fix nitrogen.

10. Lupins.—From sheep lupinosis field trials on 18 paddocks in the Moora, Dandaragan and Gingin districts, 108 samples of lupin roughage and lupin seeds from 3-monthly collections were analysed for protein, inorganic sulphate, cobalt, copper, iron, molybdenum and vitamin E.

11. Peaches.—Samples of peach leaves taken from trees under sawdust mulch at Greenbushes, in which the response to the sawdust mulch was excellent in the first year but leaf colour and size were poorer in the fourth year, were analysed for possible major element deficiency but this was not confirmed by analysis.

12. Tobacco.—581 samples of tobacco were received in 1963, more than a 3½-fold increase on the 1962 samples received in 1962. Most of these samples came from glass house trials started by the Department of Agriculture before the collapse of the tobacco industry. As there is no urgency about the samples, they will not be completed until 1964.

Samples of tobacco leaf from six growers who had been encouraged to continue for a further year in the industry, were analysed for starch, sugars before and after inversion, total and protein nitrogen, total alkaloids, nicotine, nor-nicotine, total volatile basis, ash, chloride, calcium, potassium, sodium and phosphorus in an attempt to assess their composition in relation to quality.

Animal Nutrition

1. Fading of Bovine Hair.

(a) A further 20 samples of bovine hair from a property at Keysbrook were analysed for calcium, cobalt, copper, phosphorus, selenium and zinc in an investigation of the fading of Hereford cattle hair. There was no significant relationship between degree of fading and any one of the determinations, although cobalt levels were generally higher in the brighter coloured hair. The following are the ranges and averages of the various determinations, Table 11.

TABLE 11.

Hereford Hair.

——	Range	Average
	%	%
Calcium Ca	0·10–0·38	0·25
Phosphorus P	0·02–0·03	0·025
	ppm.	ppm.
Cobalt Co	0·03–0·29	0·08
Copper Cu	3·0–30·0	7·2
Selenium Se	0·15–0·40	0·27
Zinc Zn	130–145	139

(b) 44 samples of sera were examined for β-carotene in connection with the fading of Hereford cattle hair; levels of 5-23 mgm/litre of β-carotene were found.

2. Vitamin E in Sheep Livers.—From sheep lupinosis field experiments at Moora, Dandaragan and Gingin, 120 fresh liver samples were analysed for vitamin E. These determinations were made because of the known increase in peroxidized products in lupinosis livers and the antioxidant effects of vitamin E in biological systems. These livers were found to range from 1.8 to 16 ppm. of vitamin E expressed as α-tocopherol, with an average of 5.4 ppm, all on fresh liver basis.

3. Bones.—17 samples of bone from calcium or phosphorus deficient animals were analysed for calcium, phosphorus and ash. 5 bone samples from animals fed rock-phosphate as a phosphorus supplement were analysed for fluoride, to confirm that the fluorine in the rock-phosphate was not at harmful levels.

4. Urinary Calculi.

(a) 34 samples of sheep urine from urinary calculi trials were analysed in detail and the averages and ranges of constituents are given in Table 12. From these results it can be seen that the main mineral excreted in sheep urine is potassium chloride.

TABLE 12.

Sheep Urine Analysis.

——	Range	Average
	ppm.	ppm.
Calcium, Ca	1–259	62
Chloride, Cl	55–16,000	6,330
Magnesium, Mg	5–1,100	475
Phosphorus, P*	6–88	24
Potassium, K	520–17,000	6,950
Silicon, Si	8–1,030	312
Sodium, Na	34–7,160	1,420

2 abnormal samples of urine excluded from the above had 960 and 1,270 ppm. of phosphorus.

(b) 17 samples of urinary calculi from Department of Agriculture investigations into urinary calculi were examined in detail, both by chemical and X-ray diffraction analysis. The commonest type of calculus was found to be a mixture of predominantly amorphous silica and weddellite (calcium oxalate dihydrate) with varying amounts of organic matter. The silica in this type of sample ranged from 17-60 per cent., the weddellite from 6-61 per cent. and the organic matter was found to consist of 1-10 per cent. lipoids, 1-6 per cent. hippuric acid and pigments, 4-8 per cent. uric acid and 1-4 per cent urates.

Two of the calculi were predominately siliceous having 78 and 85 per cent. amorphous silica and two were dolomitic having 63 and 78 per cent. calcium carbonate and 18 and 11 per cent. magnesium carbonate. Only one predominantly phosphate calculus was found and this was from a supplemented fed goat. This calculus was mainly tricalcium phosphate and muco-protein.

5. From urinary calculus and lupinosis trials 184 samples of sheep livers were received for copper analysis.

6. Lead in Sheep Blood.—40 samples of blood were received from the lupinosis field experiments, for the study of lead absorption and storage in lupinosis. Levels from less than 0.01-0.10 mgm of lead per litre in the blood were found, normal levels for lead in blood of sheep are quoted in the literature as 0.05-0.25 mgm per litre.

7. 10 samples of sheep and lamb kidneys were received for confirmation of White Muscle Disease diagnosis by selenium analysis. Levels of 0.8-1.5 ppm selenium confirmed possible selenium deficiency in six samples and in the others, levels of 2.1-3.5 ppm indicated the unlikelihood of selenium being involved. One unusual sample of kidney from Bridgetown had 8.6 ppm of selenium indicative of selenium dosing, although White Muscle Disease had been diagnosed in the sheep.

8. Selenium Toxicity.

(a) Samples of kidney, liver and wool from a cross-bred wether that had received fortnightly drenches of sodium selenite equivalent to a total of 70 mgm of selenium, over a period of six months were found to contain 8.4, 11.5 and 0.73 ppm of selenium respectively. The wether had deteriorated in condition over the last 3-4 months of the trial.

(b) Another sheep which had been similarly fed with 95 mgm of selenium as sodium selenite, had 2.5 ppm selenium in the liver and 1.3 ppm in the wool.

(c) From another selenium dosing trial in which selenium was fed at the rate of 5 mgm per fortnight for 12 months, samples of kidney and liver were found to contain 8.9 and 4.6 ppm of selenium respectively.

Miscellaneous

1. Spectrography.

(a) A range of mineral specimens, analytical deposits, police exhibits, agricultural samples, rocks and tin concentrates were examined by semi-quantitative emission spectrography.

(b) In August, Mr. Hughes of this Division attended the Fourth Australian Spectroscopy Conference in Canberra and gained much useful information both from the Conference and from contacts he made at the Conference. After the Conference he spent a fortnight at spectrography laboratories in Adelaide at the Australian Mineral Development Laboratories and at the C.S.I.R.O. Division of Soils. We are indebted to both these establishments for allowing Mr. Hughes to spend time observing their techniques in emission, atomic absorption and X-ray fluorescence spectroscopy.

2. Oil Seeds.—282 linseed and 20 safflower seeds from the Kimberley, Avondale and Esperance Research Stations were analysed for iodine value and/or oil content. This number of samples is approximately half the number analysed in 1962 or 1961.

3. Blood Alcohol.—A further 56 samples representing about 1 in 5 of the post mortem blood alcohols done by the Food and Drug Division, were analysed by the Kozelka and Hine method, as additional confirmation of their results because of past legal queries. Once again there was excellent agreement between their method and the Kozelka and Hine method.

4. A proprietary sample of potassium dichloroisocyanurate containing 59 per cent. available chlorine and a proprietary sample of iso-cyanuric acid were examined to test the claim made that they would maintain free chlorine in swimming pools in bright sunlight longer than chlorine from conventional sources. These claims were found to be justified and our results indicated that they would be satisfactory for use in a swimming pool.

5. A musket ball found in the head of a skeleton on Beacon Island was examined spectrographically to see if it was similar to a sample of a 17th Century musket ball, as the skeleton was thought to have been of a person from the Dutch ship "Batavia". The two musket balls were found to be quite distinct. The one from the skeleton was almost pure lead and the 17th Century one was lead and tin.

6. Two pieces of iron, one from a cannon ball from the Dutch wreck "Zeewick" and the other from an unidentified wreck believed to be Dutch were spectrographically and microscopically compared. The unknown piece of iron proved to be mainly goethite with concentric rings of magnetite, with very little metallic iron. Examination could not confirm that the two were of the same origin.

7. Corrosion, Scales and Deposits.

(a) A sample of scale from the Rottnest desalting plant was found to be almost entirely calcium carbonate with a little magnesium hydroxide. Because of difficulties in supplying sea water to the desalting plant, due to biological fouling of the inlet filters, well water from the island was being used in the plant. Laboratory tests on the well water, concentrated 1/7th under vacuum and then boiled under a vacuum of 27.7 ins. of mercury at 110°F was found to deposit scale at the rate of 3 lbs. of scale for every 200 gallons of water distilled. Sea-water under identical conditions, which are approximately the condition under which the plant operates, gave no scale.

(b) Examination of deposits from the 54 in. main from Serpentine Dam, close to the dam, showed them to be the typical soft dark, brown iron and manganese bacterial deposits. As the main is still relatively new a considerable amount of the cement lining softened by the attack of the water, was removed with the deposits. This made impossible the interpretation of differences in analysis of deposits taken at various points along the main away from the dam. Three similar deposits from the older 48 in. main from Serpentine Dam, also were similar in nature and were contaminated by the cement lining of the main. A similar deposit from the much older 30 in. main from Canning Dam was also a typical iron and manganese bacterial deposit; it had 11.6 per cent. iron, 24.5 per cent. manganese and 38 per cent. organic matter.

(c) 5 samples of soil from Roebuck Bay at Broome were examined to see if their pH or sulphate content, could explain the cracking of concrete bases of telegraph poles in this area. These two constituents were found to be at satisfactory levels, that would not affect concrete. Samples of the affected concrete were not available for further investigation of the cause.

(d) From cathodically protected steel piles at Wyndham jetty, 11 samples of deposits on the piles were examined to see if the cathodic protection applied to the piles was effective. Chemical, microscopic and X-ray examination of the deposits did not provide a complete answer. The samples all contained limonite (hydrated iron oxide $Fe_2O_3.XH_2O$) which would be formed by initial corrosion of the piles prior to application of the impressed current. They also all contained varying amounts of magnetite formed by reduction of the limonite by initial high current densities. All deposits also contained varying amounts of aragonite (calcium carbonate) and amorphous magnesium hydroxide which would be deposited by the local high alkalinity in the sea water, due to the impressed current. Suggestions were made to the Engineer, Harbour and Rivers, of the Public Works Department to instal test pieces of piles, for regular visual examination and possible cleaning and weighing as a more effective check on the efficiency of the cathodic protection.

(e) A deposit from the filtered water tank of an aerated water factory, that was causing cloudiness in some soft drinks was found to be zinc hydroxy-carbonate derived from the galvanised tanks and pipes. Recommendations were made to apply a protective coat to the tank to prevent a recurrence of the trouble.

(f) Examination of a white deposit that had blocked the circulating pump in a Department of Agriculture Farinograph was found to be magnesium hydroxide and carbonate derived from the magnesium sacrificial anode incorporated in the cooling water circuit.

(g) A sample of deposit from an evaporative condenser of an air-conditioning plant at the Government Printing Office proved to be mainly rust from not treating the cooling water to prevent corrosion. This condenser and several others examined from other places, demonstrated the problems that can occur with these commonly used condensers, without correct water treatment. This type of condenser has the gas tubes very closely packed and sealed in so that inspection and physical removal of any deposit are very difficult. A small amount of deposit can restrict the flow of the cooling water and seriously affect the efficiency of the condenser. Increased velocity of cooling water to overcome this decreased efficiency, can result in erosion corrosion of the condenser tubes at the water inlet and outlet.

(h) A 2½ in. G.W.I. cement lined pipe from the University Physics Department cooling water circuit was examined to see if the cooling water from the bore was responsible for attack on the cement lining and for corrosion of the pipes thus causing additional iron deposits in the cooling circuit. Examination showed that part of the trouble was due to faulty cement lining of the pipes. The lining had slumped to the bottom of the pipe leaving only a thin film of cement on the top and this had been attacked by the slightly aggressive water. However the main corrosion had occurred at unions of the pipes, where unsatisfactory coating of the threads of the pipes and unions with a bitumen jointing compound had caused concentrated attack on the unprotected parts of the threads. It would have been advisable in this system, if an all copper reticulation had been installed in the first instance.

(i) Scales, deposits and corrosion problems from the following sources were examined and recommendations on prevention made where possible:—a scaled pipe from Northampton reticulation, a deposit from Scarborough High School oval reticulation, a deposit in a water meter at Kondinin, an engine scale from Marble Bar, a deposit on a steriliser at Kalgoorlie Hospital, a boiler tube scale from Midland Abattoirs, 2 boiler scales from a brewery and a problem of corrosion of copper bore casing at North Fremantle.

ENGINEERING CHEMISTRY DIVISION.

During 1963 the staff of the Division increased by creation and filling of two permanent positions, viz.: Senior Chemist and Research Officer, and Laboratory Technician, Grade 1, and at the end of the year consisted of Divisional Chief, 3 graduate professional officers and a supporting staff of 9.

As in the previous year, besides advisory service to Government Departments and consultative service to industry, the Division was engaged in investigational work on bench and pilot plant scale. Though a limited number of original research projects on industrial utilisation of local raw materials was dealt with, a large proportion of the work during the year was done at the request of outside interests, this work being assigned a higher priority as compared with projects initiated by the Division itself.

Work for commercial firms is regarded as confidential and therefore only limited information concerning this is given in this report.

Further Investigations into the Process of Upgrading Ilmenite

These investigations were continued mainly to establish the factors governing the developed process, and for clarification of problems arising in connection with the operation of the pilot plant at Capel by an industrial undertaking.

Most of the work carried out during the year concerned the aeration stage of the process, i.e. the second stage when metallic iron is removed from the reduced ilmenite grains.

Among the factors established were that:

(a) Increasing the pulp density (i.e. reducing the water to mineral ratio) from 6:1 to 3:1 to 2:1 was advantageous as can be seen from the following:—

Ratio of water to mineral by weight	6:1	3:1	2:1
Time to upgrade 1 lb. of reduced ilmenite, minutes	8.5	6.9	5.4
Electricity consumed for agitation per ton of reduced ilmenite treated, kWh	164	130	132

The aeration of the 6:1 pulp was completely batchwise. The 3:1 and 2:1 pulps were aerated with partial continuous removal of iron oxides formed. This was necessary to prevent the suspension becoming so thick as to impede oxygen transfer to the suspension.

From the above Table it would appear that, on a time and power basis, it is advantageous to use a 2:1 pulp. However, the optimum ratio is that which when coupled with aeration and agitation results in minimum cost. Owing to the smallness of the equipment available, this could not be ascertained.

(b) Contrary to the opinion formed during the initial stages of process development, that an aeration temperature of about 70°-80°C was required, it was found that the reactions would proceed at a satisfactory rate at as low a temperature as 50°C. The process of aeration is considerably slower if started at ambient temperature compared with starting at about 40°C.

(c) The use of ammonium chloride instead of ammonium sulphate as catalyst did not make any difference to the process. No difference was noticed either when using ½ per cent. and 1 per cent. of catalyst.

If the amount of acid used for initial acidification, or the amount of catalyst was increased above about 1 per cent, colloidal mud may form, which retards oxygen transfer, and would make it necessary to use large quantities of diluting water in order to separate the products.

Indications were obtained that in a closed circuit with proper recovery of liquor, the make up of catalyst required would be less than 25 per cent. of the amount orginally taken.

(d) A wet magnetic separator was capable of differentiating between fractions of reduced ilmenite with a difference of only 0.1-0.2 per cent. of metallic iron. Since upgraded ilmenite is relatively non-magnetic, its separation from the intermediate, not fully upgraded, product and its removal from a continuously operated aeration system should not be a difficult problem.

(e) The oxygen efficiency, expressed as the ratio of the weight of oxygen required to oxidise completely the metallic iron in the charge to ferric oxide to the weight of oxygen introduced into the aeration vessel, was in the region of 7 to 10 per cent., the maximum attained being 12 per cent.

(f) It was concluded that possible power requirements of aeration and agitation in a commercial plant would be in the region of 0.33 kWh per pound of oxygen transferred.

(g) If the reduction of ilmenite in the first stage of the process was properly effected, i.e. 90 per cent or more of iron oxides were reduced to metallic iron, and no oxidation in situ or staining occurred during aeration, acid washing of the product will increase the TiO_2 content of upgraded ilmenite only slightly.

If, however, the reduction was inadequate in the first stage, the improvement of upgraded ilmenite by leaching with acid is more marked. For instance, upgraded ilmenite assaying 85-86 per cent. TiO_2 produced from "reduced ilmenite" which indicated only about 85 per cent. reduction of iron oxides, was further upgraded to 88.2-88.5 per cent. TiO_2 by leaching with 10 per cent. sulphuric acid or hydrochloric acid.

Utilisation of Iron Oxide from the Ilmenite Upgrading Process.

Among several possibilities considered for utilisation of iron oxide, a by-product of the process for upgrading ilmenite, its direct reduction by hydrogen to metal powder, suitable for powder metallurgy, appeared most attractive, and was selected for investigation, started in the second half of the year.

Keeping in mind that powder metallurgy is steadily gaining importance in the world, a successful solution of the problem may have an important bearing on the development of such an iron powder industry in Western Australia coupled with upgrading of ilmenite.

Indications are that the main efforts may have to be directed towards the elimination of excessive titania from the oxide since, according to references, only up to 1 per cent. of refractory oxides may be tolerated in iron powder. The dried oxide, as produced, contains about 6 per cent. of TiO_2.

Investigations carried out by the Kalgoorlie Metallurgical Laboratory on the request of the Division (Report No. 715-26.9.61) showed that it is possible to reduce the TiO_2 content of the product to around 2 per cent. by flotation, using Aeromine 3037 as collector.

Sulphur Recovery from Kalgoorlie Gold Ore Concentrate

Pending a decision concerning the continuation of the above investigations, started in 1961, the work carried out by the Division up to March of 1963 was reviewed, summarised and reported.

It was found and suggested that:—

(a) The economics of any process for recovery of elemental sulphur at Kalgoorlie would at present depend to a large extent on the payment of Commonwealth Government bounties, and on any alteration in gold recovery associated with the process.

(b) The recovery of labile sulphur only, from decomposition of pyrites to pyrrhotite, has been shown to be technically possible using an entrained bed reactor with a non-oxidising carrier gas. This conversion to pyrrhotite is a necessary first stage before hydrometallurgical oxidation of pyrrhotite to sulphur and iron oxide.

(c) Despite several difficulties, the hydrometallurgical treatment resulted in good yields of sulphur, and it may be expected that further work could establish satisfactory extraction of gold from the residues.

(d) High temperature steam hydrolysis/partial oxidation of pyrrhotite or pyrites has resulted in reasonable gold recoveries from iron oxide calcines, and has indications of good sulphur recovery. The main controlling factor in this process may be the proportion of excess steam necessary to achieve the desired reaction.

(e) Other known and proposed processes are considered to be unsuitable, or uneconomical in the present circumstances, with the possible exception of direct chlorination.

(f) The most attractive proposition would appear to be the manufacture of sulphuric acid in Kalgoorlie for use in the processing of ores found in the district (lithium, manganese, etc.)

Production of High Grade Lime from Calcareous Beach Sand

These investigations were continued during the year because of the importance of availability of high-grade lime, preferably quicklime, for the development of chemical and metallurgical industries and because of a considerable interest shown by local industrialists towards the work of the Division on production of such a lime from calcareous beach sand.

A four-stage plate electrostatic separator, equipped with pneumatic conveyor/heater, was built by the Division for larger scale sand beneficiation experiments. In the second half of the year, this separator was loaned to an industrial firm for pilot plant scale operation of the process, the staff of the Division acting as consultants.

The operation of this separator confirmed the observations made previously, that the method of heating the sand prior to beneficiation in an electrostatic separator has a profound influence on the efficiency of separation of silica from carbonates, indirect heating giving consistently good results.

Since, however, direct heating has distinct advantages over indirect heating in respect of heat requirements (if waste heat is not available), more work is proposed on a bench scale on this subject.

Calcination of beneficiated sand in the modified existing entrained bed kiln was carried out with inconclusive results, and the possibility of using falling bed technique was investigated. For this purpose a model falling bed unit was built in steel and perspex, and used for establishing basic operational data in the cold state.

Beneficiation of Impure Limestone and Hydrated Lime

At the request of a local firm, the possibilities of beneficiation of impure limestone for production of high grade lime, and that of beneficiation of lime after hydration were investigated, without achieving satisfactory results.

Production of Lightweight Aggregate

In extension of the laboratory work of the Fuel Technology Division on bloating shales from the Byford District, a ½ ton sample of such a shale was obtained and, after laboratory checks, calcined in the rotary kiln. Although bloating was induced, agglomeration of the charge within the kiln occurred causing the discontinuation of the trial. Further investigations are required before satisfactory operation could be expected. This is discussed at greater length in the report of the Fuel Technology Division.

Treatment of Diatomaceous Earth

A sample of Western Australian diatomaceous earth was received from a local firm with the request to investigate the possibilities and conditions of its calcination. After preliminary laboratory investigations, the earth was suitably calcined in the rotary kiln.

Dead Burning of Magnesite

Following a request from a local firm a sample of magnesite from the Ravensthorpe District was received for investigations into its dead burning. Conditions of such a treatment were investigated in the newly acquired oil fired heating furnace at a maximum temperature of 1700°C. This type of magnesite could probably be successfully calcined in a shaft kiln.

Investigations Into the Causes of Discoloration of Bricks

On the request of a local brick manufacturing firm, investigations, lasting over 3 months, into the causes and possible elimination of discolouration and scum formation on the pale coloured bricks, were carried out. Rates of drying, conditions of burning and cooling, and other factors were carefully examined. As a result of the work of the Division a novel procedure for eliminating the discolouration was recommended and introduced by the Company on the commercial sacle.

Upgrading of Leucoxene

The possibility of upgrading leucoxene by the process developed by the Division for upgrading ilmenite was investigated by the Division on a bench scale in 1961 and 1962 at the request of a local industry.

At the request of the same Company, this work was resumed in the last quarter of 1963 and was still in progress at the end of the year.

The Division was asked to treat a larger quantity of leucoxene in the pilot plant in order to obtain basic data for the design and layout of a commercial plant, and to estimate the cost of production of upgraded leucoxene.

The work done in previous years, and that carried out on the bench scale this year, would indicate that leucoxene can be successfully treated by this process provided that the peculiarities of leucoxene, as compared with ilmenite, are taken into account. In the case of leucoxene, supplied by the Company, these differences occur mainly in the iron content, i.e. about 15 per cent. in leucoxene instead of 32-33 per cent. in ilmenite (maximum average metallic iron content after reduction) and in the presence in leucoxene of constituents having very low (rutile) or no magnetic susceptibility.

In connection with this work, an old home-made belt magnetic separator was redesigned and rebuilt by the Division to a 3-disk high intensity "Rapid" type machine. The separator is a very versatile unit having the following possibilities for adjustment and control: magnetic flux variable in three sections separately, speed of the belt, speed of rotation and inclination of disks variable separately, and reversing the direction of rotation of the middle disk.

The separator splits the feed into six magnetic and one "non-magnetic" fractions according to the difference in magnetic susceptibility of the particles.

Investigations were in progress by the end of the year.

Pelletised Phosphate Fertiliser

The idea of pelletising rock phosphate, sulphur, and other ingredients, with the object of making soluble phosphate in situ in the soil, originated in the Division in the second half of the year. Such pellets would have certain advantages over superphosphate as such.

A literature search revealed that some work along similar lines involving rock phosphate-sulphur granules, but without the addition of other substances, has been done by the C.S.I.R.O.

A small quantity of the proposed pellets were manufactured by the Division, and the Agricultural Department was requested to carry out pot experiments with this new type of phosphate fertiliser.

General

Renovation of the main building, painting of ancillary buildings, and general beautification of the area around the buildings by planting lawn and shrubs was carried out during the year.

Among the overseas and interstate visitors, with whom fruitful discussions were held, were:

- Dr. A. W. Ellis, British Titan Products, Billingham-on-Tees, United Kingdom.
- Prof. P. W. Dankwerts, Shell Professor of Chemical Engineering, University of Cambridge, United Kingdom.
- Mr. P. A. Toynbee, Dominion Laboratory, Petone, New Zealand.
- Mr. B. Ashton and Mr. P. Moffit, Cyanamide Co. of Australia, Melbourne.
- Prof. S. R. N. Ellis, Professor of Chemical Engineering, University of Birmingham, U.K.
- Mr. S. B. Hudson, C.S.I.R.O. Ore Dressing Laboratories, Melbourne.
- I. C. Kraitzer, Associated Minerals Cons. Ltd., Southport, Queensland.
- Prof. R. H. Myers, Head of the School of Metallurgy and Pro-Vice-Chancellor of the University of New South Wales.
- Mr. Sampath, National Metallurgical Laboratories, Tungshepur, India.
- Prof. White, Professor of Metallurgy, University of Queensland.
- Dr. E. Potter, Central Electricity Generating Board, U.K.
- Dr. M. E. Hargreaves, C.S.I.R.O., Division of Tribophysics, Melbourne.
- Dr. S. S. Cole, National Lead Company, Titanium Division, South Amboy, New Jersey, U.S.A.
- Mr. J. M. Van de Plasse, Allis Chalmers, North Sydney.

FOODS, DRUGS, TOXICOLOGY AND INDUSTRIAL HYGIENE DIVISION

The greater proportion of the work of this Division in 1963 consisted of chemical examinations for the Departments of Agriculture, Police and Public Health, as well as for the Milk Board of Western Australia and the Swan River Conservation Board, but the usual variety of miscellaneous work was also performed for other departments and for the general public. An unusually large number of samples was received under the classification of Public Pay, chiefly in connection with the medical diagnosis of industrial toxicology.

The staff of the Division was short of one professional officer throughout the year, comprising in fact nine professionally qualified chemists, one laboratory technician and one laboratory assistant. As a consequence of building extensions to a portion of the Division, positions have been created for two more chemists and one technician. When appointments are made this will bring the staff to a total of 15 officers, and will greatly facilitate the Division's work.

3,279 samples were received during 1963, and represents a sharp increase over a period of three years.

A broad outline of the variations in numbers of samples over recent years is indicated in the following classification, Table 13.

TABLE 13.

Class	1960	1961	1962	1963
Milks	194	437	574	382
Cheese	84	140	71	59
Exhibits—alcohol	358	315	331	378
Human toxicology	421	388	611	649
Criminal cases	72	52	49	119
Industrial hygiene	327	335	446	233
Pesticides	24	160	231	210
Oil seeds	144	174	....	342
Pollution surveys—				
Swan River	204	178	128	128
Bunbury	48	50	50	48
Total general samples	2,436	2,901	3,177	3,279

Table 14 shows the source and description of samples received during 1963.

TABLE 14.

FOODS, DRUGS, TOXICOLOGY AND INDUSTRIAL HYGIENE DIVISION.

	Agriculture Department	Departmental	Mines Department	Police Department	Public free	Public Health Department	Public Works Department	Swan River Conservation Board	Tender Board	Other Government Departments	Pay: Air Department Commonwealth	Pay: Hospital	Pay: Milk Board	Pay: Public	Pay: Other	Total
FOODS—																
Apples	25	....	....	....	....	1	....	....	....	....	....	....	....	....	....	26
Beverages—																
alcoholic	....	....	....	7	....	2	....	....	....	....	....	....	....	1	....	10
other	....	....	....	....	....	11	....	....	....	....	....	....	....	2	....	13
Butter	25	....	....	....	....	....	....	....	....	....	....	....	....	....	....	25
Cheese	59	....	....	....	....	....	....	....	....	....	....	....	....	....	....	59
Grapes	34	....	....	....	....	....	....	....	....	....	....	....	....	....	....	34
Meat and Meat Products	....	....	....	....	....	17	....	....	....	....	1	....	....	....	....	18
Milk—																
bovine	....	....	....	....	....	6	....	....	....	....	....	....	376	....	....	382
human	....	....	....	....	....	3	....	....	....	....	....	....	....	....	....	3
Poultry tissue	47	....	....	....	....	....	....	....	....	....	....	....	....	....	....	47
Tomatoes	13	....	....	....	....	2	....	....	....	....	....	....	....	....	....	15
Vegetable oil	....	....	....	....	....	13	....	....	....	....	....	....	....	....	....	13
Other	1	....	....	....	....	13	....	....	....	....	....	....	....	1	....	15
INDUSTRIAL HYGIENE—																
Air	....	....	3	....	....	24	....	....	....	....	....	....	....	....	....	27
Urine	....	....	....	....	....	64	....	....	....	5	....	8	....	113	6	196
Other	....	....	1	....	....	7	....	....	....	....	....	2	....	....	....	10
MISCELLANEOUS—																
Air	....	....	24	....	....	....	....	....	....	....	....	....	....	3	1	28
Anaesthetic	....	....	....	....	....	....	....	....	....	....	....	9	....	....	....	9
Criminal cases	....	....	....	119	....	....	....	....	....	....	....	....	....	....	....	119
Detergents	....	....	....	....	....	....	....	....	82	....	....	....	....	....	....	82
Leather	....	....	....	....	....	....	....	....	....	....	....	....	....	9	....	9
Oats	43	....	....	....	....	....	....	....	....	....	....	....	....	....	....	43
Oil seeds—																
linseed	186	....	....	....	....	....	....	....	....	....	....	....	....	....	....	186
rape seed	144	....	....	....	....	....	....	....	....	....	....	....	....	....	....	144
other	4	....	....	....	....	....	....	....	....	....	....	....	....	4	4	12
Oxygen	....	....	....	....	....	....	....	....	....	....	24	....	....	....	....	24
Pesticides	161	1	....	....	....	34	6	....	....	....	....	....	....	8	....	210
Water	....	....	....	....	....	4	....	....	....	....	....	....	....	5	....	9
Wheat	....	....	....	....	....	....	....	....	....	....	....	....	....	19	....	19
Other	18	3	20	3	5	15	20	1	11	....	....	3	....	17	....	116
POLLUTION—																
Effluent	....	....	....	....	....	....	....	18	....	....	....	....	....	1	....	19
Maritime	....	....	....	10	....	....	....	....	....	1	....	....	....	....	....	11
Surveys—																
Bunbury	....	....	....	....	....	....	48	....	....	....	....	....	....	....	....	48
Swan River	....	....	....	....	....	....	....	126	....	....	....	....	....	....	....	126
TOXICOLOGY—																
Human, toxicology	....	....	....	634	....	3	....	....	....	....	....	12	....	....	....	649
sobriety	....	....	....	144	....	....	....	....	....	....	....	....	....	1	....	145
traffic death	....	....	....	233	....	....	....	....	....	....	....	....	....	....	....	233
specimens from Patients	....	....	....	....	....	40	....	....	....	....	....	49	....	8	....	97
Animal	42	....	....	3	....	3	....	....	....	....	....	....	....	....	....	48
	802	4	48	1,153	5	262	74	145	93	6	25	83	376	192	11	3,279

Foods

A total of 656 samples of foods was received and examined during the year. 376 of these were samples of cows' milk submitted by the Milk Board of Western Australia.

Of this number 375 were samples seized by Inspectors for checking against the standards required by the Regulations under the Milk Act. 3.0 per cent. of these samples contained less than the legal minimum of milk fat (3.2 per cent.), and 53.5 per cent. contained less than the legal minimum of solids not fat (8.5 per cent.), while 76.9 per cent. of the samples failed to comply with the legal standard for freezing point of milk (0.540 degrees Centigrade below zero). The proportion which failed to comply with the standard for fat and freezing point shows a slight improvement on the 1962 figures, but in respect of solids not fat the figure of 53.5 per cent. shows a decline on the

1961 and 1962 figures of 34.5 per cent. and 48,6 per cent. respectively. The distribution of analytical figures is shown in the following tables:—

Milk Fat

Per Cent. in Sample.	Per Cent. of Total Samples.
Less than 3.00	0.8
3.00-3.19	2.2
3.20-3.49	12.7
3.50-3.74	18.7
3.75-3.99	13.5
4.00-4.99	43.2
More than 4.99	8.9
	100.0

Milk Solids Not Fat.

Per Cent. in Sample.	Per Cent. of Total Samples.
Less than 8.00	3.2
8.00-8.24	15.7
8.25-8.49	34.6
8.50-8.74	34.4
8.75-8.99	10.5
More than 8.99	1.6
	100.0

Freezing Point.

Degrees C Below Zero.	Per Cent. of Total Samples.
Less than 0.500	0.6
0.500-0.509	0.6
0.510-0.519	2.4
0.520-0.529	18.1
0.530-0.539	55.2
0.540-0.549	22.2
More than 0.549	0.9
	100.0

In presenting this distribution of analytical figures it is emphasised that these were samples for which there was prima facie evidence of their not complying with legal standards.

59 samples of cheese were analysed for the Dairying Division of the Department of Agriculture as a check on the quality of cheese produced by factories in this State.

Of this number 61 per cent. contained more than 50 per cent. of fat calculated on the moisture-free basis, and is a decline on the 1962 figure of 87 per cent. of samples which complied with this standard.

34 samples of grapes were analysed for the Department of Agriculture in connection with the investigations into the seasonal variations in sugar and acid content of certain varieties of grapes.

The work of the Department of Agriculture on the use of diphenylamine to control "scald" in apples was continued during 1963, and 25 samples of apples were analysed to determine surface residues of diphenylamine and its concentration in the pulp of the fruit.

Samples of poultry tissue were received from a feeding experiment conducted by the Animal Division of that Department. From hens to whose feed had been added hexabunt (hexachlorobenzene), a significant concentration of organic chlorine was found in the fat, but none in the liver or muscle. From a group to whose feed had been added copper carbonate, no significant difference was found in the copper figures of liver and muscle compared with a control group.

A survey of butters manufactured and sold in this State was carried out by the Dairying Division of the Department of Agriculture and 25 samples were submitted for analysis. Of these, 3 samples failed to comply with the standard for water content.

Twelve samples of olive oil and one sample described as Blended Vegetable Oil were submitted by the Public Health Department. Extensive examination of the samples was carried out for the information of this Department, in connection with which it was found that only three samples complied with all the requirements of the Regulations.

Fifteen samples of tomatoes were analysed for Vitamin C content for the Plant Research Division of the Department of Agriculture. Further work was curtailed by the difficulty of ensuring satisfactory transport to the Laboratories in hot weather.

Samples of tomatoes received from the Public Health Department were analysed to determine the nature of the adherent white powders. These were found to be residues obviously derived from lead arsenate, but in only one sample was the arsenic concentration slightly higher than the accepted standard.

Samples of beans, brussel sprouts and apples were examined for residues of insecticides of the organic phosphorus and chlorinated hydrocarbon groups, with negative results.

A number of samples of meat possessed an unusual "chemical" odour, but analysis failed to reveal any toxic contamination. It was suggested that the meat may have absorbed some odour from sawdust which possessed a particularly strong "pine oil" type of odour, and which was present in the same room.

Other meats were examined to ascertain the nature of the artificial colourings; one sample of frankfurts was found to have a mixture of three such dyes.

Four samples of frankfurts, on analysis, were found to have a "total meat" content ranging from 64 to 73 per cent., the fat content varied from 13 to 20 per cent., and the "lean meat" from 50 to 62 per cent.

A sample of canned fish products with obvious signs of being "blown" yielded a gas consisting of 90 per cent. carbon dioxide and 10 per cent. hydrogen with a trace of aliphatic hydrocarbon. There was extensive corrosion of the internal surfaces of the can, particularly of the curved surfaces. The concentration of tin in the product was, however, only about 20 per cent. more than that of a normal can of the same product.

A sample of seeded raisins was found to be coated with paraffin oil, contrary to the requirements of the Food and Drug Regulations, but no significant concentration of any other foreign substance was detected.

The high protein content of a sample of sausages led to further examination by paper electrophoresis, but no foreign protein was detected by this means.

Imported smoked fish was found to contain a mixture of orange and red dyes which, although classed as "permitted colourings", are not permitted to be added to food of this type.

Fruit juices were analysed for saccharin, with negative result, while other samples were submitted for determination of Vitamin C content.

A sample of Kola Beer was found to contain 4 dyes, all classed as "permitted colourings" but the selective absorption of one colouring on the cork liner of the cap seal had raised a query as to the possible contamination of the sample.

Miscellaneous food samples which were examined included contaminated sugar, a food additive used as a moisture conditioner, a "home made wine" which contained 18 per cent. of "proof spirit", milk which contained talc powder as a sediment, "plastic" icing sugar, mince meats which were examined for preservatives, and a sample of icing sugar which was extensively examined in order to check for artificial "whitening agents".

Human Toxicology

Samples were received from approximately 320 cases of sudden death which were the subject of police investigation. 123 cases were as a result of "traffic accident", while 144 cases, comprising 544 exhibits, were examined for the presence of poison or other physiologically active drug.

In 44 cases no poison or drug was detected, while in 100 cases a poisonous substance or other drug was identified on analysis. In a number of cases more than one poison or drug was detected in the exhibits. Details are listed in Table 15.

TABLE 15.

Poison or Drug.	No. of Cases.
Carbon monoxide	23
Pentobarbitone	28
Amylobarbitone	11
Quinalbarbitone	7
Barbiturate (unidentified)	18
Carbromal	8
Chloral	4
Alcohol	7
Malathion	2
Strychnine	3
Cyanide	2
*Various, one of each	15
Negative	44

*Butobarbitone, phenobarbitone, glutethimide, sedormid, chlorpromazine, phenylbutazone, impramine, meprobamate, methyl alcohol, organic phosphate, amphetamine, nicotine, arsenic, lysol, sulphuric acid.

It was noted that carbromal was always associated with pentobarbitone, these being derived from ingestion of "Carbrital".

In 41 of the 103 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 16 of these cases, and between 0.05 and 0.15 per cent. in 17 cases.

From another 54 cases of sudden death other than "traffic accident", blood samples were analysed for alcohol making a total of 157 such cases of sudden death where the blood alcohol figure was determined as a routine procedure. The distribution of the blood alcohol figures is indicated in Table 16.

TABLE 16.

Alcohol Per Cent.	No. of Cases.
Negative	88
Less than 0.05	18
0.05-0.09	12
0.10-0.14	8
0.15-0.20	10
0.21-0.30	13
More than 0.30	8
	157

From the Table it will be observed that in 31 cases, i.e. 20 per cent. of the total, the blood alcohol figure was 0.15 per cent. or greater.

Blood-Alcohol (Traffic)

233 samples of blood and/or urine were received in connection with investigations into fatal traffic accidents. 123 of these consisted of "post-mortem" blood samples which were analysed for alcohol content as a routine procedure.

The distribution of the analytical figures for the various categories of persons involved in these accidents is shown in Table 17.

TABLE 17.

Alcohol Per Cent.	Number Involved		
	Drivers	Passengers	Pedestrians
Negative	22	9	21
Less than 0·05	4	....	4
0·05–0·09	6	2	1
0·10–0·14	4	4	4
0·15–0·20	18	2	2
0·21–0·30	12	1	6
More than 0·30	....	....	1
	66	18	39

Table 17 indicates that 45 per cent. of fatally injured drivers had a blood alcohol figure of 0.15 per cent. or more, while the corresponding figure for passengers and pedestrians was 17 per cent. and 23 per cent. respectively.

Voluntary Blood Alcohol Tests

144 samples of blood were submitted by the Police Department and one by a Local Government Authority in connection with charges of "driving while under the influence of intoxicating liquor". These samples were taken from persons who, on being charged with such offence, had exercised the right provided by the Traffic Act to have a blood sample taken by a doctor and submitted for chemical analyses.

The Traffic Act states that if the alcohol content of the blood at the time of the alleged offence is 0.15 per cent. or greater it shall be prima facie evidence that the accused was under the influence of intoxicating liquor at that time. The results of these analyses are set out in the following Table, the figures being the alcohol content of the blood at the time of the alleged offence, calculated by the formula prescribed in the Blood Alcohol Test Regulations:—

Alcohol Per Cent.	No. of Cases
Less than 0.15	6
0.15-0.20	43
0.21-0.25	59
0.26-0.30	27
More than 0.30	10
	145

Animal Toxicology

Although there was a decrease in the number of samples received in connection with suspected poisoning of animals, the proportion of positive cases was much higher than normal. Of the 20 cases which were received and examined, only 5 were found to be negative, while there were 10 cases of poisoning due to strychnine, 3 due to arsenic and 2 due to lead.

The Animal Health Branch of the Department of Agriculture continued its investigation into Vitamin A deficiency and in this connection 9 samples of animal liver were analysed for Vitamin A content.

Only five samples of suspected poison baits were received for examination. Two of these contained strychnine.

Industrial Hygiene

233 samples were examined during the year in connection with industrial hygiene investigations.

152 of these were specimens of urine from persons exposed to suspected lead hazard. The specimens were submitted for analysis in order to assist clinical diagnosis, or in some instances as part of a "screening" to exclude the possibility of undue exposure. 61.8 per cent. of these specimens contained less than 0.08 part per million (milligram per litre) of lead which is generally accepted as the normal upper limit. The range of figures obtained in these analyses is shown in the following Table:—

Lead (Pb) Parts Per Million.	Per Cent. of Samples.
Less than 0.08	61.8
0.09-0.15	25.7
0.16-0.20	5.9
More than 0.20	6.6

113 analyses of urine and several of blood, hair and nails were also carried out to detect toxic metals, although not all of these were associated with industrial hygiene as such. These consisted of analyses for arsenic 62, copper 15, lead 29, mercury 2, and thallium 4.

There was a reduction in the number of miscellaneous samples handled in connection with industrial hygiene investigations.

Three samples of air were analysed following complaints of an odour of sulphur dioxide from a nearby works; nine samples were taken and examined from a factory using tolyl di-isocyanate in the manufacture of "plastic foams", while checks were made of the concentration of carbon tetrachloride in the vicinity of a machine making waxed paper bags and using an adhesive alleged to contain 50 per cent. of this solvent.

Examinations were also made of a process room where benzene was used and samples of urine from an employee were analysed for phenol content as a check on exposure.

The use of malathion for the control of weevils in export wheat led to analyses of the air in which men were working during loading operations, while 19 samples of wheat were analysed to check the content of malathion of wheat from a number of storage bins.

Air from an assay office was examined to check the concentration of lead dust or fume, while the pad from a respirator used by a worker was also examined as a guide to lead exposure.

Work was continued for the Public Health Department on the possible absorption of sodium fluoroacetate as a fine dust during the commercial formulation of poisoned oats for use against the rabbit pest.

Examination of air in the hold of a cargo vessel was carried out in order to check that conditions were safe for the unloading of the cargo of cyanide.

Pollution Surveys

1. Swan River.—The regular quarterly surveys of the Swan River were continued in 1963 when 144 samples were analysed for the Swan River Conservation Board. 108 of these were samples of river water from normal sampling points, while 18 additional samples were examined from two investigations to trace the degree of pollution from a specific source. 18 samples of trade effluents were also examined as a check on their suitability for discharge into the river.

2. Leschenault Inlet, Bunbury.—The normal summer and winter surveys were carried out in February and July when 48 samples were collected and analysed. As observed during the previous year the degree of pollution was greater in the winter but the general position has improved since steps were taken to divert to sea much of the effluent which once discharged into the Inlet.

3. Maritime.—Eleven samples of suspected oil were received and examined. These were alleged to have been discharged from ships into the waters of Fremantle Harbour, and were analysed in order to provide supporting evidence that they were in fact, oil, or substance of a similar nature.

Miscellaneous

1. Waters.—Few samples were examined during 1963 for suspected contamination of water.

Samples from water bags used in the "bush" were received following the illness of persons but no poisons were detected which could account for the symptoms described.

Samples from streams in different localities were analysed for chlorinated hydrocarbon type insecticides following reported heavy mortality of fish, but no evidence of such contamination could be found. One sample, however, had an unusually low concentration of dissolved oxygen.

Another sample was examined for phenolic substances following suspected contamination of streams by tar products, while a check on an unusual chemical contamination of underground water, which commenced in 1960, showed that phenolic substances, and chloro derivatives of phenoxyacetic acid were still present in the water.

2. Pesticides.—Although the number of pesticides received in 1963 was somewhat less than in 1962, the variety of samples was more extensive, as shown in Table 18.

TABLE 18.

Pesticide.	No. of Samples.
Weedicides (2:4D type)	68
Weedicides (commercial formulations)	12
Dieldrin (commercial formulations)	8
Dieldrin (solid)	7
Dieldrin (concentrate)	18
Dieldrin (diluted emulsions)	6
Chlordane (concentrate)	4
Malathion (concentrate)	5
Aldrin (concentrate)	1
D.D.T. (concentrate)	5
Endrin (concentrate)	2
Kelthane	1
Tedion	1
D.D.T.—Endrin mixture	1
Malathion (commercial formulation)	9
Malathion fruit fly baits	28
Fly spray	1
Aircraft tank washings	25

Although the commercial formulations are listed under the name of the principal constituent, many of these samples consisted of mixtures of insecticides, and entailed considerable work for their separation and quantitative determination. This work was carried out for the Pesticides Advisory Committee of the Public Health Department as a check on the composition of pesticides registered with that Department.

Attention was directed to the possible contamination by weedicide residues, of insecticides used for entomological purposes, and a number of samples were submitted for this type of examination. A considerable amount of work was carried out, in an emergency, on an aircraft tank intended to hold such insecticides, in order to ensure that no harmful residue remained of weedicide which it had previously contained.

The samples of dieldrin (diluted emulsion) were analysed for the Architectural Division, Public Works Department, in connection with white ant preventive treatments, and as a further check on the efficiency of application a number of samples of soil from treatment sites were also examined for dieldrin content.

Miscellaneous samples included a sample of D.D.T. which was found to be contaminated with a 2:4D type of weedicide, grasses which were examined for residues of dieldrin, and a sample of sheep's wool submitted in order to check the presence of diazinon.

3. Criminal Cases.—There was a relatively large increase in the number of exhibits received in connection with criminal investigations or other police inquiries. Samples of corrugated iron and wheat were examined in connection with cases of suspected theft, and 9 samples of detergents were investigated in an inquiry into the possibility of misrepresentation. Following eight separate instances of illness of persons, samples of tea, coffee, "Gravox", confectionery, grapes, drugs, milk and other exhibits were analysed for possible poisons with negative results.

Paint flakes and other varied exhibits were examined in connection with accidents, some fatal, involving motor vehicles, while a large number of miscellaneous materials were submitted during the course of inquiries into the origin of a fire which occurred on board ship. The value of infra red spectrophotometry was particularly evident in this case, which involved the examination and comparison of mixtures of organic materials.

Amongst exhibits from a fire on industrial premises was a partly burnt rag which contained partly oxidised linseed oil, but the actual cause of the fire could not be determined from the chemical examination.

In connection with a "breaking and entering" offence, a screwdriver was submitted with dried reddish-brown paint covering 4½ inches of its blade. A tin of paint, 4½ inches in depth, containing paint of the same shade of colour as that on the screwdriver, and identical in lustre was also submitted. "Infra red" examination showed however that the paint vehicle of one was an alkyd resin, while the vehicle of the other was an epoxy-ester resin.

4. General.—82 samples classified under detergents were received from the Government Tender Board. These ranged from relatively simple synthetic detergents to composite soap powders, laundry adjuncts, liquid soap type cleaners with deodorant properties, steam cleaning compounds, and detergent type preparations for highly specialised uses. Extensive consideration was necessary in order to advise the Tender Board as to those which were most suitable for use in Government institutions.

Other samples submitted by the Tender Board included floor polishes and laundry starches which were examined to determine their relative suitability for the purposes required by the Board.

Of the materials classed as drugs or medicines, eleven were samples of local anaesthetics. Following reports of untoward reactions by some patients these anaesthetics were analysed to investigate the possibility that the reactions might be the result of chemical deterioration but analysis did not disclose any reason for the clinical symptoms.

A sample of powder labelled as Kaolin proved on analysis to be dextrin, and a proprietary brand of tablets, whilst undoubtedly of some therapeutic value, were quite unsuitable for the purpose for which they were advertised.

Some capsules were submitted for identification, and sedative tablets and a liquid preparation used as an analgesic were assayed as a check on their conformity to label.

Work for the Department of Air was continued with the examination of 24 samples of "high altitude" oxygen. A laboratory check of each batch was carried out, in addition to normal factory inspection tests, to ensure that this oxygen conforms to the exacting specifications required by the R.A.A.F.

Investigations were again carried out by the Mines Department into the decomposition products of different explosive mixtures, and 24 samples of mine air were analysed variously for oxygen, carbon dioxide, carbon monoxide and oxides of nitrogen.

Interest in the purity of the compressed air obtained from cylinders used for underwater swimming was reflected in the analyses of a number of such airs to check that they conformed to acceptable standards.

Four samples of building materials were tested for "fire resistance" in order to assist the Public Health Department assess their suitability for use in public buildings.

Eight samples of fireworks known as "streamer bombs" were examined for the Explosives Branch. All were found to contain antimony, and some a trace of arsenic, which was considered to be an impurity in the antimony.

Five unusual samples were examined for the Explosives Branch in an endeavour to determine the cause for "migration" of one constituent of an explosive to the lining and wall of the container box.

The concern of the Explosives Branch about the admixture of organic matter with ammonium nitrate resulted in four commercial samples of this explosive being submitted. A method was developed for the quantitative estimation of organic matter.

Samples of earth thought to be associated with mineral oil were found to contain products of decaying vegetable matter, while a lump of material washed up by the sea proved to be, not ambergris, but partially hydrolysed animal fat.

Samples of lubricating oil were examined, in one case to investigate the source of corrosion and in another to provide evidence of crankcase dilution.

An extensive examination was made of a "medicated wine" which did not comply with the requirements of the Food and Drug Regulations, while other wines were submitted by the Liquors Inspection Branch for analysis for alcohol content and the possibility of prohibited "additions".

A sample of carbide used underground in miners' lamps was examined for compliance with specifications following complaints by users; a slightly increased amount of phosphorus impurity was considered to be the most likely cause of trouble.

186 samples of linseed and 144 samples of flax seed were analysed for oil content in connection with various experimental projects being carried out by the Department of Agriculture.

43 samples of poisoned oats were also analysed for the Vermin Branch of that Department in connection with the use of sodium fluoroacetate for vermin destruction.

Miscellaneous samples received and examined during the year included hypochlorite antiseptics for available chlorine content and stability on storage, child's toy for inflammability, cattle dipping fluids, cotton seeds for insecticide residues, hydrometers for checking of accuracy, leathers for examination to Commonwealth Government specifications, tallows for analysis to trade requirements, "battery tailings" for cyanide content, resins and plastic materials for identification, sandalwood oil for comparison with approved standards, as well as materials such as paper towels, waste newsprint, glass-wool, safflower seed and paint thinners.

The usual inquiries for technical information and advice were received during the year, and expert evidence was tendered as required in Criminal, Coroner's and other Courts by Messrs. Sedgman, Uren, Katnic, Double, McLinden, and Mulder in connection with their official duties.

During the year portion of the Laboratory space has been "out of commission" while building alterations and extensions have been in progress. This has caused considerable inconvenience and has added to the difficulties under which the Division has had to carry on its work. When these present extensions are completed the increase in staff which is anticipated should give some relief to the conflict, which has existed for some years, between the pressure of routine type activities, and the need to investigate problems raised by technological advances, particularly in the fields of foodstuffs, synthetic drugs and pesticides.

FUEL TECHNOLOGY DIVISION

General

Air pollution examination and prevention have occupied a major part of our time in Fuel Technology during 1963. A programme of twelve months dust deposition measurement in the Rivervale and East Perth areas was completed. A report for the Air Pollution Committee has been prepared. Dust emission and deposition from the Swan Portland Cement Company's works were measured and reported on for the Chief Inspector of Factories. Two other occurrences of pollution were examined and reported. This work is now well within the scope of the Division and can become of a routine nature if it is decided to allocate the responsibility to us. Our report with the Air Pollution Committee suggests that pollution in the Perth area or anywhere else in the State will not rise to levels which will call for a separate laboratory to deal with sampling and analysis.

Size analysis of dusts is related to air pollution and we are now doing these as a routine determination and, as well, interest in this work is being sought in the Eastern States with a view to getting Australian standardisation of methods and results of determination.

Work on dust arrestment plant and devices has now commenced at the Engineering Chemistry Division laboratory at Bentley and an extensive testing programme is proposed in a field which is now of interest in all industrial communities because of the general world interest in clean air and arrestment of dust and other pollution. A major object of the work is to study methods in which low pressure loss is associated with reasonable efficiency of dust collection.

Work on light weight aggregates of concrete has gone forward and one source of suitable bloating shale has been found near Perth. Fundamental studies of the cause and behaviour of bloating of shales are being made with a view to making the best use of the materials which we have in the State. This is necessary as so far as can be seen the State is not well endowed with such materials and this could prove a disability in the development of the light weight concretes which are becoming increasingly popular elsewhere in structural engineering to obtain economical strength to weight ratios in buildings, bridges and other works.

TABLE 19.

Fuel Technology Division.

——	Departmental	Factories Department	Local Government Department	Other Government Departments	Public Free	Public Pay	Public Works Department	Total
Atmospheric pollution	37	14	111	1	....	1	....	164
Boiler corrosion	....	....	....	....	....	....	9	9
Coal	5	....	....	....	....	65	....	70
Dust extraction	2	....	....	1	....	25	....	28
Hot water units	....	....	....	8	....	....	....	8
Lightweight aggregates	19	....	....	....	....	....	....	19
Pyrometry	....	....	....	2	....	18	....	20
Size analysis	....	....	....	....	....	7	....	7
Miscellaneous	8	....	....	7	1	13	2	31
	71	14	111	19	1	129	11	356

Two visits to Collie have been made for routine sampling of working mines. Clay samples taken from faces of open cuts have been examined for brick making qualities and suitable materials have been found. A brick industry at Collie for the South-West of the State seems possible.

A number of other clays have been examined in conjunction with the Mineral Division to assess brick making and ceramic properties.

Domestic storage water heaters of the solid fuel type have been tested for the State Housing Commission for performance and efficiency. In the course of this work it has been realised that we have not, as yet, built up experience or information on the durability in service of copper hot water tanks sealed with modern brazing alloys.

One example of flue corrosion of an oil fired boiler has been brought to our notice and is under observation. It appears that a hot water boiler fired with oil containing sulphur must normally suffer from sulphuric acid attack brought about by condensation below 200°F. This can be minimised by suitable operation of the boiler on an on-off schedule instead of on lowfire-high fire. Alternatively ammonia can be injected into the combustion zone to neutralise sulphuric acid.

Incidental work which has come to us has been assistance in the design of a crop drier for preparation of lucerne meal, thermal conductivity measurements and the thermal expansion of a fibre-glass plastic effluent pipe, a figure which is surprisingly high and was of some concern to the users in providing for it over long runs of pipe.

A wood fired pottery kiln design was developed which may be useful and of interest to some of the growing number of home potters who want to fire ware without the expense or size limitations of electric kilns.

Air Pollution

Work for the Air Pollution Committee and investigation of occurrences of atmospheric pollution have enabled a clear picture of the extent and nature of existing pollution to be obtained and of possible increase in pollution in the future industrial development of the State. The Committee had great help in its work from the Commonwealth Bureau of Meteorology of the Department of the Interior, an association which has been most valuable.

The picture formed is reassuring. The weather and wind pattern of Perth and the South-West of the State provides adequate atmospheric ventilation both through thermal, vertical air movement and horizontal wind movement. Our fuels are relatively smokeless. Industry is generously dispersed. In consequence pollution at the present time is slight; heavy, general pollution, as the result of industrial growth, is unlikely.

The major contribution to low level pollution in Perth is dust, sand and grit from the roads and loose, sandy surfaces. As can be expected this is much less in winter when surfaces are moist and rain washed than in summer when they are dry. At the present time pollution of this nature must be much less than in the past when road surfaces were of unsealed gravel or limestone.

High level pollution is the cause of frequent haze over Perth which has the appearance of industrial pollution. The Weather Bureau has indicated that this haze is almost exclusively associated with wind borne dust of inland origin. It may also be aggravated by bush fires, the smoke from which can cause quite heavy pollution for several days at a time and greatly exceeds in severity any present industrial contribution to pollution.

Attention has also been called to the possibility of pollution from industrial development in the Kwinana-Cockburn Sound area producing objectionably high concentrations of pollutants, especially of sulphur oxides. Under the conditions of low level atmospheric inversions which commonly occur on cold clear nights low lying land behind the industrial area might be affected and slight air movement from the South-West could carry pollution over the metropolitan area. There are indeed suggestions that this is already occurring. The cure for it appears to lie in discharge of combustion gases and other pollution at a sufficient height and in such condition that they rise through low level inversions so that they cannot back diffuse to reach the ground again.

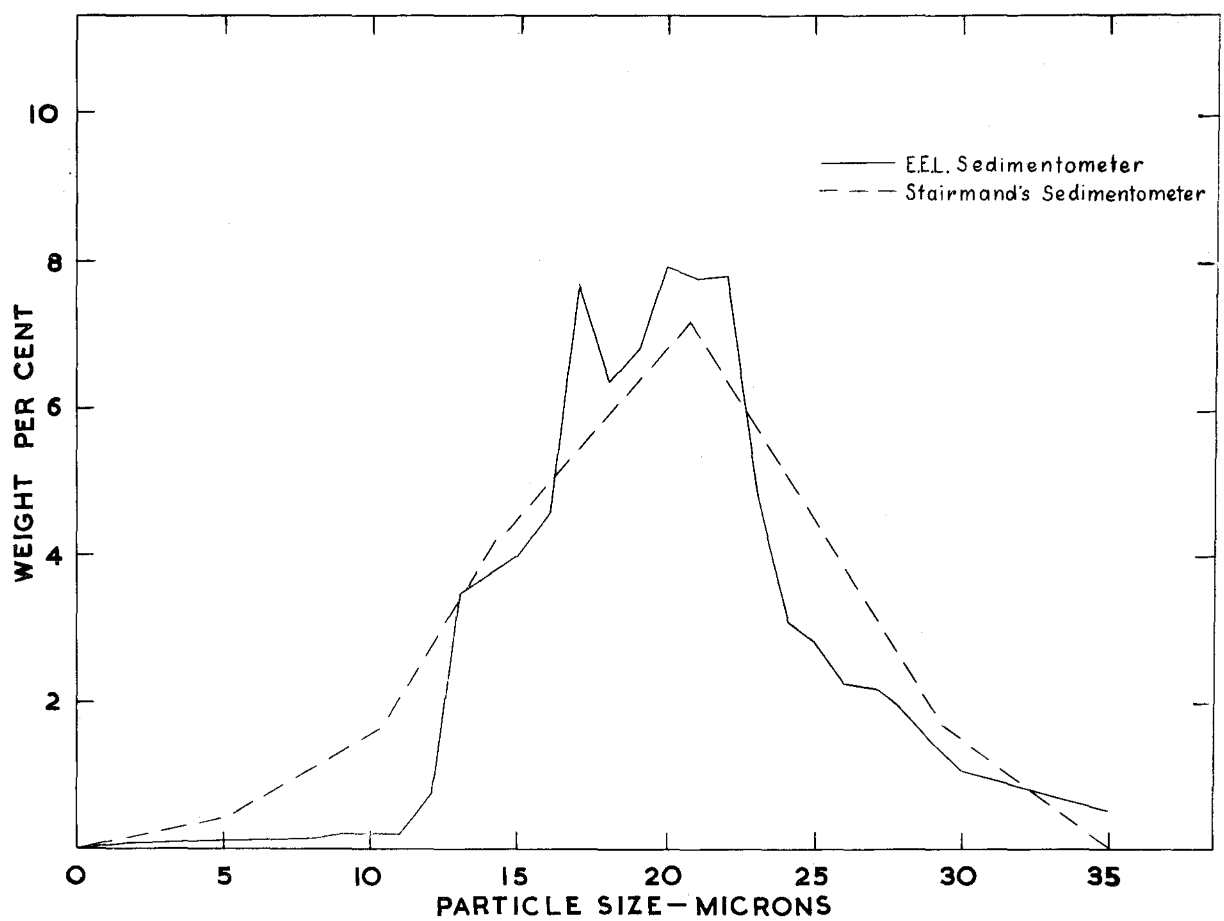
TABLE 20

Dust Deposition 1963—East Perth and Rivervale Areas.

Test Position	Rate of deposition tons per sq. mile per year					
	Summer			Winter		
	Max.	Av.	Min.	Max.	Av.	Min.
Perth Oval	490	260	120	180	80	5
Perth Modelling Works	440	360	320	400	130	40
Plant Engineer, Jewell Street—						
4 ft. above ground	1350	470	150	330	220	70
10 ft. above ground	410	290	200	330	135	45
30 ft. above ground	280	240	200	350	130	40
East Perth Power Station	270	235	170	80	45	20
Rivervale near cement works	490	215	110	1,000	145	15

In England figures of greater than 500 tons per sq. ml. per yr. are characteristic of heavily industrialised areas, 200-400 occur in average urban conditions and rural conditions are below 50.

Table 20 gives figures for dust deposition at sites at Rivervale and East Perth. The dust collected at these sites is mainly fine sand and other surface dust. At Rivervale there is some limestone either from road surfaces or from materials-handling at the nearby cement works. On the East Perth sites surface dust is again predominant but there is as well some coal which probably comes from coal handling plant in the neighbourhood. On all sites there is very little dust characteristic of discharges from the various industrial chimney stacks in the areas. The conclusion suggested is that so long as industrial dusts are too fine to settle readily and they are discharged at an adequate height their contribution to dust in the air is unlikely to make any noticeable addition to the natural surface dusts which occur in our atmosphere.



COMPARATIVE PARTICLE SIZE DISTRIBUTION OF E.E.L. SEDIMENTOMETER AND STAIRMAND'S SEDIMENTOMETER ON 10–20 MICRON FRACTION FROM AIR ELUTRIATOR

FIG. 1

This view appears to be supported by an investigation of dust emission from the chimneys of a cement works which in the past has been the cause of considerable complaints from nearby residential areas. The investigation has shown that aerodynamic cones used for dust extraction on the chimneys from the cement kilns remove all dust above 50 microns size and between 100 per cent. and 70 per cent. of the dust between 50 microns and 20 microns. As dust below 50 microns is not readily settleable the use of aerodynamic cones appears to provide an acceptable solution in this specific application. Their performance is of technical interest because dust removal is effected with the efficiency characteristic of high capacity cyclones but at an overall lower pressure loss with an associated saving in power. The separators can be operated at as low a loss as 0.5" w.g. although figures of 1.5" are more usual. Cyclone pressure losses are normally of the order of 3" to 4" w.g. See Tables 21, 22.

TABLE 21.

Size Analysis of Cement Kiln Chimney Dust Remaining after Aerodynamic Cones.

Lab. No. 1963	2996	2997
	No. 1 Chimney	No. 2 Chimney
Size, microns—	% by weight	% by weight
above 50	1	1
—50 + 20	14	4
—20 + 10	29	17
—10 + 5	28	41
below 5	28	37
	100	100

TABLE 22.

Weights and Efficiency of Dust Removal from Chimney Gases by Aerodynamic Cones.

Size of dust microns	Removed by cones, etc.	Discharged by chimneys	Efficiency of dust removal
	tons per day	tons per day	%
Above 66	0·9	....	100
—66 + 40	2·7	....	100
—40 + 30	1·5	negligible	almost 100
—30 + 20	1·5	0·6	71
—20 + 10	2·2	1·3	63
—10 + 5	0·4	2·1	16
Below 5	0·8	1·9	30
	10·0	5·9	Average 63

An example of the value of adequate dissipation of effluent gases as the solution of their disposal was provided by a poultry feed pellet plant on which our advice was asked. In the course of manufacture the pellets are cooled and dried by drawing air over them. The air becomes charged with water vapour and acquires the meaty odour of the pellets. This air was being discharged just above the roof of a tall building. Its odour was a frequent source of complaint from residents living close to the plant on its north and east sides, that is to leeward in the prevailing wind.

We were in the first place asked to advise on the purification of the effluent air. Its volume was about 2,000,000 c.ft. per day and its saturation temperature about 100°F and this would present a considerable problem in cooling and deodorisation.

The alternative course of discharge of the gases at an adequate height above the plant buildings was therefore suggested. The standard height of 2.5 times the height of the buildings was recommended for the top of an 8-10" diameter vent. At this height the effluent gases would not be drawn down into the leeward vacuum created by fresh winds. The existing arrangement of venting at roof height brought about a condition in which the air passing over the roofs became charged with the vent gases which were then carried down to ground level in the lee of the plant in odorous concentrations.

Work has been done on the continuing problem of emission of smuts from sawdust fired boiler plant. We were asked to test a new dust arrestor installed on an automatically fired range of boilers. The performance of the collector was inadequate and the method of automatic firing used produced irregular combustion conditions which aggravated the smut emission. The need for a better controlled and more adequate method of firing was indicated which could possibly have cured the problem without recourse to use of high efficiency dust arrestors. The use of preheated air with forced draught fans will probably provide the solution to smut emission from sawdust fired boilers and, as well, raise their efficiency. The alternative is to use multicones or high efficiency cyclones and accept the associated need for fans to overcome cyclone resistance. Of the two approaches the former is the better and lower in power and installation costs which will both be recovered in increased efficiency.

Particle Size Analysis

Sub-sieve size particle analysis has now been developed to a routine determination using the air elutriation roller apparatus and the EEL photoelectric sedimentometer. The latter has been improved by the acquisition of taller cells which give a longer time of settlement which is particularly valuable in making readings for the larger, rapidly settling particles whose effects fade rapidly over the first few minutes of the determination as they settle so rapidly out of the field of observation.

The two methods are in fair agreement. It is proposed to use the EEL with a recording galvanometer which will make the determination largely automatic.

The need for standardisation of particle size analysis has been raised with others interested in the same field of work in New South Wales with a view to exchanging samples, establishing reference samples and comparing different methods of analysis and types of apparatus.

Samples analysed comprised two cement kiln dust samples, four iron oxide dust samples from roasters for sulphuric acid manufacture and one sample of high grade lime.

The analysis of the lime indicated a concentration of silica material in the coarser fractions suggesting that the purity of the material could be increased by air classification.

Comparative analyses are appended in Tables 23 and 24 showing the degree of agreement between the Roller air elutriator and the EEL sedimentometer on the same sample, and between the EEL and the Stairmand sedimentometers—See also Fig 1.

TABLE 23.

9866.

Iron Oxide.

Size, micron	Roller elutriator	EEL sedimentometer
	%	%
Above 50	17	17
—50 + 40	5	8
—40 + 25	14	12
—25 + 15	24	24
—15 + 10	14	18
—10 + 5	18	18
— 5 + 3	8	2
Below 3	negligible	1

TABLE 24.

Finely Ground Silica Prepared in the Laboratory.

Fraction separated in roller elutriator	Same fraction examined			
	in EEL sedimentometer		in Stairmand sedimentometer	
micron	micron	%	micron	%
0– 5	0– 5	54	....	....
	5– 8	34	....	....
	8–14	12	....	....
5–10	0– 5	9	....	....
	5–10	23	....	....
	10–14	49	....	....
	14–24	19	....	....
10–20	0–10	2	0– 9	5
	10–20	52	9–18	26
	20–28	38	18–25	52
	28–40	8	25–35	17

Light Weight Aggregates

An examination of the Armadale-Cardup brick making shales has shown that a black shale from this series has valuable bloating properties which should enable it to be used in making light weight aggregates for concrete. The shales cannot be used to any great extent in brickmaking because the clinkering and bloating properties spoil bricks if they are incorporated in any quantity in brick making mixes.

These black shales are interspersed regularly through the Cardup shales from Armadale down to Mundijong. Their bloating behaviour is provided by a combination of sharp fluxing at 1150°C-1200°C accompanied by a considerable evolution of gas over this temperature range. The fluxing is a characteristic of the illite which has been estimated to occur in these shales in amounts as high as 85 per cent. The gas evolution is caused by the interaction of carbon with combined oxygen in the shale, most probably with iron oxide.

The amount of gas evolved from these shales is as much as 9.0 mls (N.T.P.) per gram of shale. Only about 0.5 ml. (N.T.P.) of gas is required to produce a controlled, finely pored bloat in a shale. These Cardup shales therefore tend to overbloat. Additionally they flux too readily either because of their high illite content or because reduction of iron oxide by carbon produces sufficient ferrous iron to lower the viscosity of the fluxing shale.

The shales therefore tended to overbloat and fuse into an unmanageable sponge of material when they were treated in a rotary kiln although in the laboratory they formed an excellent pelleted material. This has lead to a quantitative investigation of gas evolution from bloating shales and the quantities of gas evolved at temperatures above 1,000°C have been measured and their composition determined by gas analysis. The results are a little surprising in showing the presence of hydrogen as well as carbon monoxide and dioxide. This indicates that water is retained in the shales to temperatures in excess of 1,000°C. A view expressed by U.S.A. workers that bloating is caused by carbon dioxide produced by delayed decomposition of carbonates is also disproved. The gases formed are characteristic of the reduction of metallic oxides by carbon and their volume is related to the amount of carbon initially in the shale giving a reasonably good balance between the carbon determined in gravimetric analysis and the amount evolved in bloating. These results are set out in Table 25.

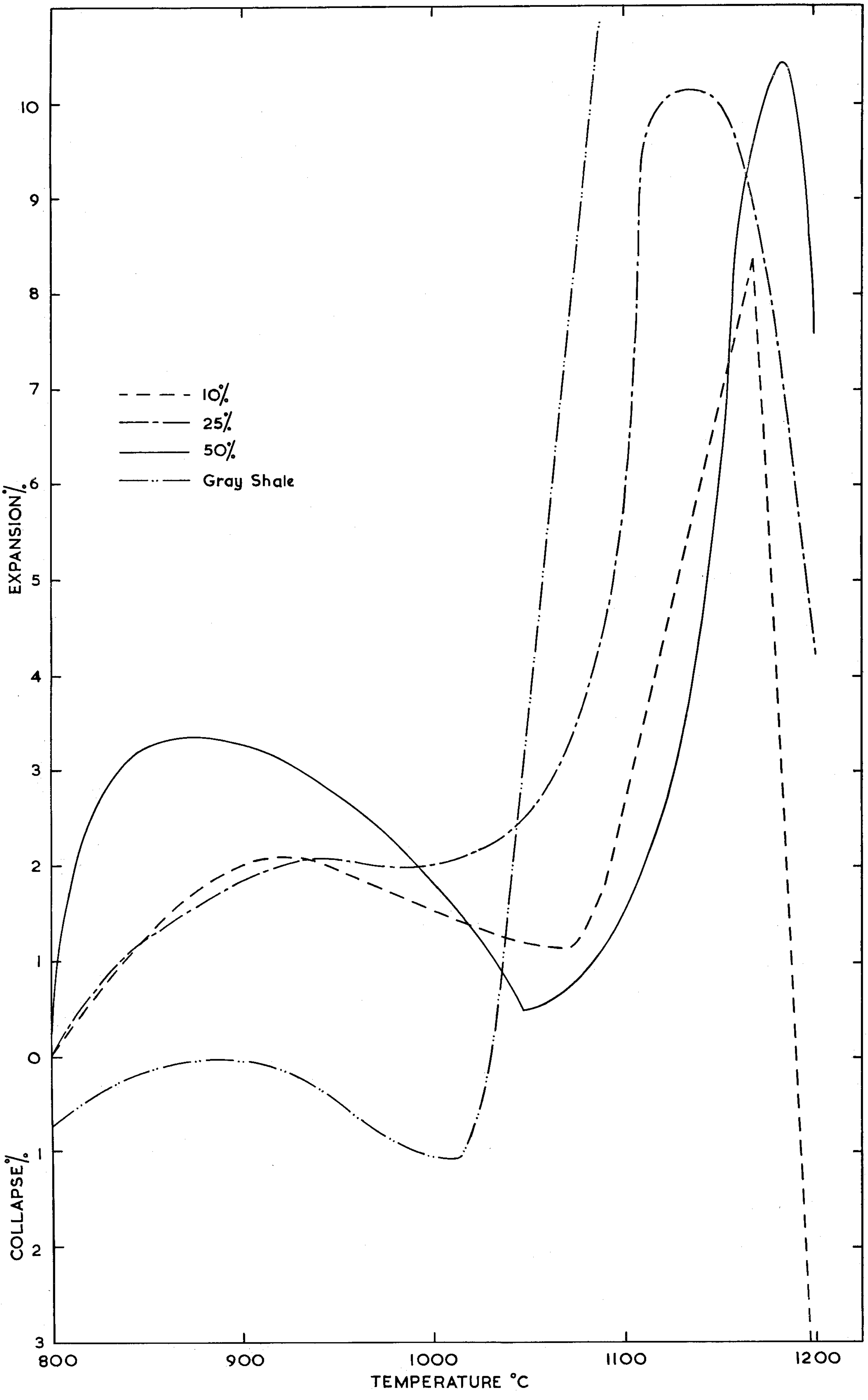
The evident further step in this work is to blend the bloating Cardup shale with other non-bloating materials of similar fusion point to provide a more controllable material.

Complete analyses by the Mineral Division of samples taken from Bedfordale quarry at the Armadale end of the Cardup series show that the bloating shales are of a siliceous type with about 6.0 per cent. of K_2O and about 0.8 per cent. of organic carbon as distinct from carbonate carbon and graphite. The carbonate is low and graphite is not present, Table 26.

TABLE 25.

Sample	Hawker-Siddeley grey shale				Maldon Shale ex C.S.I.R.O.			South Marong ex C.S.I.R.O.		Reid's Quarry ex C.S.I.R.O.		Midland Brick Co. + 2·5% oil
Lab. No.	6531/63				1975/62			1977/62		9819/63		4477/62
Temperature °C	900–1,150	1,100–1,250	1,075–1,140	1,065–1,185	625–855	855–985	985–1,120	625–1,070	1,070–1,175	850–1,215	870–1,195	870–1,195
Gas evolution— ml. (N.T.P.) per gram ...	6	9	below 1	2	3	5	14	1–2	6	1	below 1	2
Gas analysis—	%	%	%	%	%	%	%	%	%	%	%	%
Carbon dioxide (a)	19·0	6·5	1·1	15·6	†48·4	†29·1	*7·8	†43·0	*11·5	82·1	22·8	14·6
Carbon monoxide	53·2	70·4	87·4	74·2	15·5	38·4	67·0	25·0	47·6	12·8	65·8	63·8
Hydrogen	27·5	22·6	9·2	9·3	35·1	32·2	25·1	29·7	40·2	2·2	5·3	20·5
Oxygen (b)	0·3	0·5	2·3	0·9	1·0	0·3	0·1	2·3	0·7	2·9	6·1	1·1

(a) This figure includes sulphur dioxide and hydrogen sulphide if present. The asterisk (*) indicates that hydrogen sulphide was definitely present. The dagger (†) indicates that hydrogen sulphide was not detected.
(b) This oxygen could come either from residual air left in the apparatus or from dissociation of Fe_2O_3 in the shale.



BLOATING OF BRICK MAKING CLAY WITH ADMIXTURE OF INDICATED PERCENTAGE OF BLOATING SHALE

FIG. 2

TABLE 26.

Lab. No.	Bloating Shales—Bedfordale		
	1604/63	1605/63	1606/63
	Per cent. (dry basis)	per cent. (dry basis)	per cent. (dry basis)
Silica, SiO_2	64·1	63·9	65·9
Alumina, Al_2O_3	16·0	15·8	15·9
Titania, TiO_2	0·54	0·57	0·64
Iron oxide, Fe_2O_3	4·78	4·62	4·04
Calcium oxide, CaO	0·08	Nil	0·19
Magnesium Oxide, MgO	3·47	3·47	3·31
Potassium oxide, K_2O	6·24	5·79	5·52
Sodium oxide, Na_2O	0·18	0·09	1·0
Sulphate sulphur, SO_4	N.D.	Trace	0·06
Sulphide sulphur, S	N.D.	Trace	Nil
Carbon as CO_2	0·16	Trace	0·03
Organic carbon	0·79	0·88	0·80
Graphitic carbon	Nil	Nil	Nil
Colour	Black	Black	Grey

Samples of green and red shales were taken from the same quarry. These did not bloat. From their colour it was adjudged that carbon was absent. They were also lower in alkali oxide content, Table 27.

TABLE 27.

	Non-Bloating Shales Bedfordale	
Lab. No.	1608/63	1609/63
	Per cent. dry basis	
Na_2O	0·75	0·066
K_2O	1·49	0·46

Similar bloating shales Lab. Nos. 3318-20 were obtained from Hawker-Siddeley quarries at Cardup. All these bloated well when heated to 1260°C giving materials with specific gravities ranging from 0.931 to 0.527, finely pored material with a hard, fused, impervious outer skin. It was a feature of their behaviour that they could be held at 1200°C for periods up to one hour and then raised rapidly to 1260°C causing them to bloat. Bloating took place mainly through expansion between the bedding planes of the shale, that is the shale exfoliated in much the same way as vermiculite does.

Samples of the same shale were also taken from Mundijong at the south end of the same beds and at Cardup from behind Metropolitan Brick Works. The exposure at Mundijong is an excellent one in the side of a railway cutting and enables detailed sampling to be made of all the shales in the various beds which are now folded up and lie at about 60° to the horizontal. The behaviour and analysis of each shale are as follows:—

Lab. No. 4484.—A white shale which by X-ray examination appears to be 85 per cent. illite, 10 per cent. quartz and 5 per cent. kaolinite. Analysis shows its Na_2O content is 0.12 per cent. and K_2O is 2.06 per cent. corresponding with only 30-40 per cent. of illite which is however sufficient to give the material adequate fluxing properties for brickmaking. Refractoriness tests show that a good brick could be produced at 1200°C without bloating. Its carbon content is only 0.04 per cent.

Lab. No. 4485.—A yellow shale low in illite and mainly quartz and kaolinite. Analysis returns Na_2O-0.16 per cent., K_2O-0.04 per cent. corresponding with the foregoing estimate of composition by X-ray examination. The shale forms a soft brick at 1100°C which does not shrink any further up to 1400°C. This shale therefore has good refractory properties. Carbon content is only 0.04 per cent.

Lab. No. 4486.—A grey shale which bloats satisfactorily at about 1200°C. It contains Na_2O-0.89 per cent., K_2O-4.17 per cent. which would correspond to 60-70 per cent. illite. X-ray examination estimates its illite content at 85 per cent. Its carbon content is 0.75 per cent. organic carbon and 0.10 per cent. graphitic carbon. The association of the readily fluxing illite with carbon brings about the characteristic bloating behaviour.

Lab. No. 6324.—A grey shale from behind Cardup brickworks containing: SiO_2-66.4 per cent., Al_2O_3-15.3 per cent., Na_2O-0.16 per cent., K_2O-5.23 per cent., C-1.2 per cent. The material bloated satisfactorily. This material was further mixed and pelletised with 10, 25 and 50 per cent. of sedimentary non-bloating clay from the Midland district and successful bloating was achieved with all these mixtures as shown in the curves of Fig. 2.

The laboratory identification and characterisation of these Cardup bloating shales now seemed to be complete. A pilot scale trial was therefore required. This was undertaken by the Engineering Chemistry Division at Bentley in their 14 inch diameter rotary kiln on a bulk sample from Hawker-Siddeley quarry (Lab. No. 6531). The fluxing and bloating characteristics of this sample are characteristic as indicated by the high K_2O and carbon contents:—K_2O-5.66 per cent., carbonate C-0.06 per cent., organic C-0.58 per cent., graphitic C-0.13 per cent. The bloating characteristics of the shale were normal.

The shale bloated excellently in the rotary kiln at a temperature between 1200°C and 1250°C but, as well, agglomerated into masses which were too big for discharge. The angle and speed of the kiln were varied to control agglomeration but without success. Operation at slightly reduced temperatures stopped both bloating and agglomeration.

Agglomeration is said to be avoided in large kilns by operation at high peripheral speeds of up to 15 r.p.m. The Engineering Chemistry Division Kiln operated at only 6 r.p.m. which in conjunction with its small diameter gave only low peripheral speeds. No doubt with higher speeds in larger kilns the bloating material is carried in and out of the hottest fluxing zone so that the material bloats without agglomeration. Furthermore sand is often added to separate pieces of shale by infusible material.

Nevertheless a sample of a commercially bloated material from Victoria was obtained Lab. No. 9819. This bloated with an expansion of up to 22.0 per cent. at 1150°C. The bloated material produced was finely pored and strong in appearance. Commercial samples of the bloated product have a specific gravity of about 1.0 and look like small grey pebbles with a rough but almost impervious skin. It is desirable in light aggregates to produce a fused, impervious outer skin as this reduces the amount of water absorbed by the aggregate and reduces the bulk weight of mixes and their drying time. On the other hand an open pored material will take cement and sand into large pores and so increase the weights of mixes and the final concrete.

The raw shale contained less potassium oxide and less carbon than our Cardup black shale. This would give a more viscous slag with a lower and more restrained bloat than the Cardup shale. The analysis for the material is K_2O-3.73 per cent., carbonate C-0.03 per cent., organic C-0.29 per cent., graphitic C-nil.

Measurements of gas evolution at temperatures over 1,000°C have been made on both materials and on a mixture of Midland brick making clay with oil, the function of the oil being to provide residual carbon in finely divided form which can react with the clay to provide bloating gases at fluxing temperature. The volumes and compositions of these gases are set out in Table 25.

Lab. Nos. 5291-2/63 were samples of river clays from Carnarvon which fluxed readily at 1050°C-1100°C and bloated considerably. Illite and other readily fluxed minerals are present in these clays with, as well, 1.5 per cent. of carbon. The clays are too far from Perth to be of importance but their characterisation suggests that similar estuarine mud could be dredged from the Swan River and blended with other components to give a bloatable mixture based on freely available supplies of raw materials.

Refractory Tests

A number of tests of clays have been made independently of the work on bloating and light weight refractories. Five samples from Carnarvon, two from Esperance, two from Collie, one from Albany and three from Mundijong were characterised for the type of brick which they would provide and the burning characteristics which could be expected. Some of this work was carried out in conjunction with Mineral Division. A feature of the work is the appreciation of the importance of the mineral illite as a fluxing constituent of many of the clays and shales examined.

We have now acquired a British Refractories Research Association refractoriness under load furnace and a pyrometric cone equivalent test furnace. An oil fired furnace has also been adapted to test whole brick samples. These additions will be of value in the future, especially in the testing of firebricks and other high duty refractories.

Coal Sampling and Analysis

Coal has been sampled from the Griffin and Western Collieries mines at Collie. The quality of the coal remains good in respect of its low ash content. The characteristic higher calorific value of the Western No. 4 bottom seam persists. Coal samples have also been sent in by one consumer up to October of this year. Since October he has discontinued the use of coal in favour of oil, Table 28.

TABLE 28.

Average Analyses of Collie Coal Samples 1963 from the Coal Faces.

Mine Seam	Muja Colliery Hebe	Western No. 2	Western No. 4	
			Top	Bottom
	%	%	%	%
Proximate analysis—				
Moisture	27·6	27·5	24·6	25·6
Ash	2·4	4·5	6·6	3·6
Volatile matter	27·1	26·1	22·6	25·5
Fixed carbon	42·9	41·9	46·2	45·3
	100·0	100·0	100·0	100·0
	B.t.u. per pound	B.t.u. per pound	B.t.u. per pound	B.t.u. per pound
Gross calorfic value	8.970	8,660	8,910	9,560

Average Analysis of Collie Coal Submitted by Private Consumer, January to October, 1963.

Analysis.	Per Cent.
Moisture	26.6
Ash	4.1
	B.t.u. Per Pound.
Gross calorific value	8820

Crop Drying

A lucerne grower who wished to build his own drying plant for the production of lucerne meal was assisted with some basic calculations for the design of his plant. It was impossible to provide him with any practical assistance as he was not in a position to pay for this. His object was to replace lucerne meal imported from Victoria with W.A. produced meal. Lucerne meal is extensively used in poultry mashes for its protein and vitamin content and to improve the colour of egg yolk.

It would at least be valuable to obtain some performance results from this plant for guidance in an activity which may become of importance in poultry raising. The plant is fired with oil and its resistance to condensation corrosion may have an important influence on its success.

Miscellaneous

The thermal expansion of a fibre glass effluent pipe was measured and a value of 2.2×10^{-5} - 2.6×10^{-5} per F. deg. reported which could give a total expansion per mile of 13.7 inches for an anticipated maximum temperature rise of 100°F.

The thermal conductivity of a specimen of talc was measured and reported as set out in Table 29.

TABLE 29.

Hot Face Temperature	Thermal Conductivity	
	Cal/cm sec deg. C	Btu/ft h deg. F
deg. C	Unfired talc	
400	$0{\cdot}98 \times 10^{-3}$	0·24
600	$1{\cdot}42 \times 10^{-3}$	0·34
800	$1{\cdot}92 \times 10^{-3}$	0·46
900	$2{\cdot}27 \times 10^{-3}$	0·55
	Talc fired to 1,100°C	
400	$0{\cdot}99 \times 10^{-3}$	0·24
600	$1{\cdot}26 \times 10^{-3}$	0·30
900	$1{\cdot}82 \times 10^{-3}$	0·44

INDUSTRIAL CHEMISTRY DIVISION

Introduction

In the variety of work carried out by the Division in 1963, the pattern in general was much the same as in 1962 and 1961, but there were some slight, but possibly significant, shifts of emphasis. The consultant service continued to grow and new clientele came forward more frequently; more inquiries than ever came from the larger firms and even from the Navy and R.A.A.F.; plastics assumed a more important role in our activities; more time was spent than ever before, on short-term investigational work. The staff increased in numbers by one on the addition of a laboratory technician, and although this benefit is offset by the extra week's leave granted the service, nevertheless the general effect may be to increase productivity.

Staff

Mr. A. Reid, Divisional Chief, was appointed lecturer in Reinforced Plastics for the evening classes at Carlisle Technical School and delivered a course of 18 x 2 hour lectures. In 1964 this class will be continued, and there will be an additional class for R.A.A.F. personnel, and an advanced class in tooling resins and plastics forming.

Mr. A. Reid visited Melbourne in October and attended meetings of the Federal Technical Committee of the Plastics Institute of Australia. He also consulted technical experts on the plastics testing equipment which it is proposed to add to the Division's technical apparatus.

Classification of Work

As previously the work falls broadly into the following categories:—

(a) Routine.
(b) Short term investigations.
(c) Long term investigations.
(d) Consultant work.

TABLE 30.

Industrial Chemistry Division.

	Departmental	Government Stores Department	Main Roads Department	Metropolitan Water Supply	Public Health Department	Public Pay	Public Works Department	Total
Building Material —								
Cement and concrete	....	....	....	....	....	31	4	35
Tile	....	....	....	....	....	2	10	12
Other	....	....	....	....	....	1	4	5
Paint	....	....	3	....	....	3	34	40
Plastics—								
Resin	....	....	....	11	....	....	6	17
Fibre Glass	....	....	....	....	....	....	14	14
P.V.C. Pipe	....	....	....	....	....	....	10	10
Other	....	....	....	....	1	1	1	3
Miscellaneous	2	4	....	....	....	14	7	27
	2	4	3	11	1	52	90	163

Routine

It is doubtful if any "routine" work, in the strict dictionary sense of the word, was carried out. Of the 163 samples examined (Table 30) practically everyone was associated with short or long-term development work. This is as it should be if the functions of the Division are to continue as assistance to Government Departments and to Secondary Industry. As industry continues to develop standards and specifications for articles and equipment used by Government Departments it is quite clear that we must develop testing systems to evaluate products used by these Departments and routine testing must shortly again develop as a major activity of the Division. Meanwhile we must concentrate on the preliminary work, as for example on testing of plastic products to which later reference is made. It should clearly be understood that, whereas in well-established activities of the Laboratories procedures and methods are already well established, in the burgeoning field of industry these standards, specifications and procedures are the subject of from day to day investigations, and the function of Industrial Chemistry Division at the moment is largely to follow these trends. At the moment the Division does only a little testing in the routine sense, but as methods, standards, specifications develop, a very important section of the Division's activities must inevitably be routine testing. At the moment we are in the course of developing an organisation to cope with this type of work as will be clear in references in other sections of this report.

Short Term Investigations

Description of this work is somewhat limited by the fact that a number of the investigations were of a confidential nature and details cannot be revealed. What follows is a summary of work other than that of a confidential nature.

(1) Ord River Dam Paints.—Some of the vinyl paints used on this project had been in store at the Ord River Dam Project for upwards of one year. The paints had shown distinct changes in viscosity—that is they had apparently become "thicker" or "heavier". The problem was, had these paints become unuseable or were they likely to deteriorate rapidly after application? It was found that the paints had not unsurprisingly, developed "thixotropy", a condition which has been described as the twilight between complete stability of the constituents and the settling of the solid components of the mix.

It was found that the degree of thixotropy developed was not harmful practically speaking and that the paints could be used, as they have been, without any reasonable doubt of success in application.

This work involved an unusual approach to paint testing. We had to "throw away the book" and rely on tests based on theoretical principles.

(2) Laporte Pipe Line.—This pipe line, the longest (3 miles) and first of its type in Australia, involved the coating of P.V.C. pipe with laminated layers of fibreglass and polyester resin. In the preliminary stages it was necessary to find which of the samples submitted by tenderers was the best for the purpose. Later the Division had to "police" the application of the resin/fibre glass coating to the P.V.C. and to test samples for conformity with the specifications and procedures recommended by the Division. There were numerous problems of technique and application to be solved and, that they were solved is in itself a tribute to the co-operation of the applicators, the Public Works Department, and the Division. The work showed that as a Division we were not well equipped for this type of work, and with comparable work rapidly developing in the future steps are being taken to place the laboratories in a better position for future testing, advisory, and development work.

As an outcome of this and other similar work the Division has become recognised as the local authority on reinforced plastics, and this has resulted in the laboratories having an important voice in the deliberations of the Federal Technical Committee of the Plastics Institute of Australia which has praised the work done by the Division. The work, too, has had important repercussions in the teaching of reinforced plastics at Carlisle Technical School, where the present syllabus has been used as a guide to similar courses in the Eastern States. Reinforced plastics are a very important and developing industry in W.A. and the Laboratories are fortunate in being in on the ground floor of its development.

(3) Painting of "Dimet" Coated Surfaces.—This has long been a thorny problem for the painting industry and particularly in W.A. where exposure conditions are recognised as the most severe in the Commonwealth.

Present recommendations conform to those suggested by the Division as a result of investigations and tests at our Exposure Station. Some idea of the reason for failures in particular has been obtained, but there is still much to do and a sound painting system has yet to be developed. Nevertheless results have improved and the percentage of failures reduced.

(4) Paint Exposure Tests.—The true test of a paint's capability to withstand the somewhat meretricious nature of W.A. conditions lies in tests of paint exposed to these actual conditions. It is now recognised that tests in Victoria, New South Wales, and Queensland are not a true indication of what can be expected in W.A.

The Division has for some years had an exposure station at South Fremantle but it has been recognised that this station, which has given excellent results, covers only a fraction of the atmospheric conditions which can be expected in this State. As a result exposure stations are shortly to be established near Mount Yokine Pumping Station and at Welshpool. Extensions of the exposure station organisation to country areas in the North West, South West and Eastern areas of the State will have to follow and are now being studied.

In investigating the establishment of the new exposure stations deficiencies in equipment and procedure have been revealed and much time and thought has been devoted towards making the new stations more efficient, and the results therefrom much more informative. The results will be evident when the new stations begin to operate in 1964.

(5) Surface Coatings.—The chemical composition of a proprietary grade of surface coatings was determined and on this basis the expected behaviour of these in actual use was predicted.

(6) Coatings for Raincoats.—Samples of local manufacture examined for water proofness did not meet specifications, and suggestions for improvement were made.

(7) Plastic Linings for Cast Iron Pipe.—The nature of these linings was determined. They were of epoxyester type and their expected performance in use was determined.

(8) Paint Failure.—A failure of paint on a city building was found to be due to the formation of sodium sulphate in the plaster. Remedial procedures were suggested.

(9) Chalkboards.—Three samples of chalkboards were examined for performance. It was found that the inclusion of fine silicon carbide in the surface layers materially improved the product.

(10) Traffic Paints.—Tests in a dust-bin weatherometer indicated that the inclusion of glass reflector beads in traffic paints materially improved the light-fastness of the paints concerned.

(11) Efflorescence in Cement Bricks.—Investigations on the prevention of efflorescence in cement bricks involved the analysis for free lime in 27 samples submitted by a local firm. It was clearly indicated that the free lime in the bricks is probably responsible for efflorescence and that the amount can be reduced by varying process conditions and by certain appropriate additives.

(12) Sandalwood.—Two samples were steam distilled to determine oil content, the work being related to potential overseas markets for the material.

Long Term Investigations

In an internal reorganisation of the Division it was found possible to allot to each chemist a research project on which he may work when other and more immediate work permits. Following is a summary of the present status of these projects.

(1) Painting of Karri Timber.—Work done on this project in the past five years has been reported and as a result a proposed painting system has been developed. At the moment of writing this system has been used on a number of occasions and indications are that results are good.

Much, however, remains to be done and preparations for a new series of tests are well advanced.

(2) Non-slip Preparations for Flooring.—Accidents due to slipping, particularly amongst school children, but also in Government offices has focussed attention on anti-slip preparations. Laboratory investigation quickly showed that there was no reliable and satisfactory method of determining slip under conditions closely resembling those found in practice. Research has now designed a method believed to be satisfactory and capable of reproducible results. The most interesting feature of this work so far has been the discovery that what may be called the "tendency-to-slip" is not a function, as was thought of the velocity of the slipping foot, but the rate of change of that velocity, acceleration. A report on the first stages of this work will appear next year.

(3) Vinyl Tiles.—The increasing popularity of vinyl tiles as a floor covering and the variety in which they appear on the market have raised a few problems for those whose task it is to specify them for particular jobs, and for end-users generally. What sort of tile is best suited for a specific set of circumstances? What properties and what standard tests best indicate the potential "life" of a tile? How exactly does one define a "flexible" tile? How is the flexibility related, if at all, to such properties as foot comfort, noise level when walked on, and "life" expectancy? Answers to these and other queries are being sought in an investigation on the many types of tiles now being sold in W.A. The research was suggested by Public Works Department architects.

Some early results have proved interesting and have been applied in practice. A report on this work is due shortly.

(4) Testing of Plastics.—Some 12 years ago W.A. produced in the State some £30,000 of plastics goods, valued at factory. In 1963 estimates place the figure as high as £500,000. This tremendous expansion clearly indicates that W.A. as a whole is becoming a bigger and bigger consumer of plastics. Government Departments now buy very appreciable quantities of plastic material and it has become quite evident in the past two years that the laboratories must be in a position to test the plastic materials purchased and used by other Departments and to provide data which will facilitate correct purchase.

The Plastics Institute of Australia, whose policy it is to maintain as high a standard as possible of plastic goods in Australia, has combined with the Standards Association of Australia to produce a considerable number of standards for various plastic goods.

Realising that the Government Laboratories would in due course be requested to carry out tests to these standards, the problem of selecting and obtaining the most suitable testing equipment was tackled two years ago and investigations have continued since. There have been a number of points to consider such as the testing range to be expected, frequency of testing, reliability and capacity of equipment available, cost, air-conditioning facilities for testing and so on. Several pieces of equipment have been made for the Division by a Government Department and have proved most acceptable. Some smaller items are now on order or will be ordered shortly. The more sophisticated and expensive equipment has been given most attention and a report and recommendation will be ready in March, provided inquiries now in hand are satisfactorily answered. The work of selection has involved much library research, catalogue studies, correspondence with authorities and suppliers in Australia, Great Britain, Germany, the U.S.A. and Japan. During his visit to Melbourne the writer consulted several authorities and discussed the problem informally with the Federal Technical Committee of the Plastics Institute of Australia.

(5) Manufacture of Lithium Salts.—A very good market exists abroad for lithium salts. The possibilities of devising a suitable manufacturing process for obtaining these salts from lepidolite and petalite are being investigated. Preliminary work will probably occupy some time.

Consultant Work

This work now occupies the major part of the time of the Chief of the Division. We may assume the service is successful from such facts as the increasing crop of new clients, mostly recommended by existing clients; many clients continuing to consult us over a period of years (16 years in two cases); the increasing interest and co-operation of local manufacturers and suppliers.

The character of the work is changing. In early days many of the inquiries were from "small" men, starting up businesses or conducting businesses with little hopes of expansion, and even from curiosity seekers. In 1963 we had consultations with representatives of quite a number of leading firms, and the "small" man while still there was receding more and more into the background. The work, too, has become more and more confidential in nature.

At one time of every two inquiries received one, at least, could be answered "off the cuff". Last year one in four could be so answered.

To maintain this service and keep it efficient more and more recourse must be had to technical literature and more and more facts must be committed to a card index rather than to the fallible brain of a chemist.

The Division makes much use of the Laboratory library and owes much to the librarian but the card-indexing is more and more a task for the Division itself.

As been mentioned practically all of the consultant work is of a confidential nature and precise examples cannot be cited in a report of this nature. Perhaps the following facts will reveal its scope—and it is hoped—its value.

(a) Never less than six inquiries by personal call or telephone have been received in one day. The last two occasions in which this number was reached were the Thursday before Good Friday 1963, and the 23rd December.

(b) On a very broad average the number of inquiries per working day is 10.

(c) The following classes of people have made inquiries:—Shopkeepers, architects, teachers, manufacturers, clergymen, medical men, builders, agents and manufacturers' representatives, technical associations, trade unions, industrial chemists, chain stores, and housewives as well as most Government Departments whose calls are over 50 per cent. of those currently received.

(d) It is believed that the award of some contracts, the settlement of some disputes, and the procedure adopted to solve certain problems, have been based on the advice received from the Division's consultant service.

(e) The Division numbers amongst its inquirers technical men from Switzerland, Germany, the U.K., U.S.A., France, and the Eastern States of Australia.

The Future

Part of the control which must be applied to the almost head-long development of secondary industry in W.A. is clearly vested in the Laboratories and by its very position, the Industrial Chemistry Division must play its part in the manufacturing, marketing and progressive development aspects, and in consultant work. The Division's contribution will be less and less to heavy industry, but more and more to light industry, to the organic field and in particular to plastics and paints. Developments continually condition our thinking in these matters.

Acknowledgement

The Division—and this includes all its members—are deeply grateful to industry and to Government Departments for their help and co-operation in 1963.

MINERALOGY, MINERAL TECHNOLOGY AND GEOCHEMISTRY DIVISION

General

The total number of samples examined during the year was 2,678, an increase of about two hundred over the previous year.

The main sources of samples were:—

General public (free)	837
General public (pay)	744
Departmental	241
Geological Survey Branch	229
State Batteries Branch	165
United States Navy	178

Table 31 details the nature and source of samples received during 1963.

TABLE 31.
Mineral Division.

	Public		Geological Survey	Public Works Department	Departmental	State Batteries	Agriculture Department	U.S. Navy	Public Health Department	Local Government Department	State Mining Engineer	Others	Total
	Pay	Free											
Aggregates	41	....	....	23	9	....	....	....	....	....	....	2	75
Alloys	29	....	....	....	....	....	....	....	....	....	....	10	39
Burnt Lime	10	....	....	1	....	8	....	....	....	....	....	2	21
Clays	9	6	....	....	5	....	1	....	....	....	....	15	36
Corrosion	....	....	....	....	....	....	....	178	....	....	....	....	178
Dusts	2	....	....	....	12	....	....	....	22	100	....	10	146
Mineral Identifications	45	336	24	1	174	....	23	....	....	....	1	10	614
Minerals and Ores—													
Beryl	25	15	....	...	1	....	....	....	....	....	....	....	41
Copper	41	148	2	....	....	....	....	....	....	....	19	1	211
Gold Ore	198	86	....	....	....	....	....	....	....	....	7	....	291
Gold Tailings	....	....	....	....	....	104	....	....	....	....	....	....	104
Gold Umpires	....	....	....	....	....	21	....	....	....	....	....	....	21
Gypsum	10	26	....	....	....	....	....	....	....	....	....	....	36
Heavy Sands	1	12	18	....	....	....	....	....	....	....	....	....	31
Iron	38	90	122	....	....	....	....	....	....	....	....	4	254
Limestone and sand	42	23	....	....	....	....	....	....	....	....	....	....	65
Lithium	8	17	2	....	....	....	....	....	....	....	....	....	27
Tantalite-Columbite	71	17	....	....	....	....	....	....	....	....	....	....	88
Tin	81	5	....	....	9	2	....	....	....	....	....	....	97
Titanium	4	11	....	....	25	....	....	....	....	....	....	....	40
Miscellaneous	32	45	43	....	4	3	....	....	....	....	....	....	127
Miscellaneous Investigations	56	....	4	13	2	27	1	....	1	....	....	17	121
Complete Analyses	1	....	14	....	....	....	....	....	....	....	....	....	15
Total	744	837	229	38	241	165	25	178	23	100	27	71	2,678

In addition to the Mines Department and its Branches, sixteen Government departments or instrumentalities submitted samples for examination. Of these, three were Commonwealth, namely C.S.I.R.O., Civil Aviation and Customs.

Staff

No staff changes occurred during the year. Mr. J. Bialecki, Assayer, completed the Diploma in Pure Chemistry at the Perth Technical College.

Mr. G. Payne was a member of a party of geologists and mineralogists which visited mineral deposits in the South West, Eucla and Central Divisions of W.A., during the second half of March. The eight members of the party were drawn from C.S.I.R.O., Geological Surveys of Western Australia, and the Government Chemical Laboratories and the opportunity was taken to examine a large variety of deposits, during the 2,200 mile trip.

Localities and deposits visited included Bunbury-Busselton (beach sands), Greenbushes (tin), Ravensthorpe (copper, pegmatites, spongolite, manganese, magnesite), Young River (vermiculite), Munglinup (graphite), Norseman (pyrite, gold, opal), Widgiemooltha (copper, salt), Coolgardie (pegmatite minerals, particularly spodumene), Kalgoorlie (gold), Boorabbin (halloysite), Southern Cross (gold), Koolyanobbing (iron) and Chandler (alunite).

Over 60 samples were brought back to the Mineral Division for examination, many of which were added to the Division's mineral collection.

Later in the year the same officer revisited Ravensthorpe where a 30 ft. cut through the Catlin Creek pegmatite had then been completed by a mining company. The new faces exposed were of great mineralogical interest. A particularly good range of copper and cobalt minerals was also collected during this trip.

Mr. D. Burns, while visiting Malaya on private business was given the opportunity while there of examining a number of tin deposits and treatment plants and inspecting laboratories including those of the Malayan Mines Department, the Geological Survey and commercial organisations. Much useful information was acquired particularly in regard to problems associated with the chemical determination of tin in a range of tin products.

In October, Messrs. L. Hodge and R. Pepper spent some time locating and mapping the pegmatite in the Poona area from which specimens of the rare bismuth-tungsten mineral russellite had been identified. A number of further specimens were obtained, both of the russellite and the host rock and when the examination of these has been completed it is hoped to publish a paper on the occurrence. The Dalgaranga and Mt. Magnet fields were visited on the return journey.

Once again we are able to record our appreciation of the whole-hearted co-operation shown to our officers during these trips by prospectors, local authorities, company and government officials.

Mineral Collections

About 150 specimens were added to the Mineral Division Collection during the year, bringing the total number to 3,517.

All were of West Australian origin except 15 from overseas and 7 from interstate. Though it is not policy to seek overseas exchanges, requests originating from responsible bodies are met whenever possible. As a result, we have received Canadian specimens of the following minerals from the Geological Survey of Canada: strontianite, pentlandite, amber, pollucite, jamesonite, datolite, niocalite and britholite and from Ecole Nationale Superieure des Mines Paris a specimen of the rare earth mineral hibonite. Typical specimens of cassiterite, xenotime, monazite, scheelite and zircon from the Kinta Valley, Malaya were brought back by the Second-in-Charge of this Division from Malaya.

An overseas mineral of particular interest was obtained through Department of Industrial Development. It was quartz from Brazil, of the grade required by U.K., manufacturers of fused silica ware and was much superior to any clear quartz from this State.

Six specimens from South Australia and Victoria donated by the C.S.I.R.O. Division of Applied Mineralogy, were added to the collection as reference material, the seventh addition from interstate being a specimen of inesite from Broken Hill (see also under Mineral Identifications).

An appreciable number (43) of the local specimens were collected during field trips by officers of the Division, mainly from deposits in the South West and lower Central divisions. Those of particular interest will be described elsewhere.

A series of ten cave minerals, mainly various forms of calcite, were acquired during the year. The remaining additions to the collection were obtained through the Geological Survey of Western Australia, prospectors, mineral buyers and the general public.

Registration of the 4,949 specimens in the Simpson Collection has been completed and preparation of a card index is well advanced. Though the value of this collection has increased greatly since re-housing and re-classifying its full potential as a reference collection will not be realised until a complete card index is available.

Both the Mineral Division and Simpson Collections are invaluable to members of the staff, and frequent requests are received from outside interests to examine specimens.

Among visitors to the collections were Dr. B. Mason, Chairman of the Department of Mineralogy of the American Museum of Natural History and Mr. E. P. Henderson, curator of the U.S. National Museum. It was pleasing to be able to provide these gentlemen with specimens of Londonderry bavenite and bityite for their respective museums.

An increasing number of requests are received each year for collections of W.A. minerals and in view of this steady growth it has become necessary to limit the number of collections supplied. Twenty seven sets were made available during 1963, seven of which went to schools for educational purposes, five to prospectors, and a dozen to interested members of the public. A number of clay specimens were sent to C.S.I.R.O. Division of Applied Mineralogy in Melbourne, a series of carbonate minerals to research workers at the University of New South Wales, and fairly typical collections to the Geological Survey of Burma and to a technical school in Nebraska, U.S.A.

Building Materials

1. Cement and Concrete: (a) Aggregates.—The work referred to in the Annual Report for 1962 dealing with the Fitzroy River aggregates has been completed.

The mortar-bar expansion tests were run for 12 months.

At the end of this period there was no significant expansion, indicating that the aggregates were not reactive towards the alkali of the cement used. This result is as expected from previous petrographic work carried out on the samples, though the accelerated chemical reactivity tests had indicated that some of the aggregates were slightly suspect.

The three methods of testing aggregates practised in these Laboratories comprise petrographic examination, an accelerated chemical reactivity test and mortar-bar tests. The first two can be completed in two days, the last in 6 to 12 months. The latter is, short of full-scale field trials the most satisfactory but is very time consuming.

The results of the work on Fitzroy aggregate have indicated that the accelerated chemical test is nevertheless a valuable pointer. It is a conservative one in that it is most unlikely to classify a dangerous aggregate as innocuous, though it may cast doubts on a safe material.

As well as bars made from Fitzroy material, the above series of mortar-bar tests included a number of bars in which the aggregate consisted of various mixtures of inert quartz sand and reactive opal.

Superficial expectation would be that those bars containing the greatest percentage of reactive opal would show the greatest expansion. This is not so. In fact, almost the reverse is true, the greatest expansion (0.14 per cent.) being shown with aggregate containing the least opal (2 per cent.). The magnitude of this expansion would have been much greater had high alkali cement been used but the results were regarded as being more significant if the normal cement at present commercially available were used.

Expansion is considered to be a function involving three factors, namely the relative amounts of reactive component, alkali and water and for each type of reactive component there is an optimum ratio at which maximum expansion takes place.

With a cement of constant alkali content and a mix containing a standard water content; the reactive component becomes the only variable.

Varying this component (as opal)between 2 per cent. and 100 per cent. of the total aggregate gave results illustrated in Fig. 3 which clearly shows the greatest expansion at the lowest opal content. This was not necessarily the maximum expansion that could have been registered; higher figures may have been obtained at say 1.0 per cent. or 3.0 per cent. opal but to obtain accurately this maximum (or "pessimum") figure would have required a large number of bars with opal contents varying by very small amounts over the range 0.1 per cent. to about 4 per cent. Unfortunately, neither the staff nor the equipment was available for this work.

The reactions with which we are concerned take place between the opal, the alkali and the water. The reaction products, are alkali silicates (or better, alkali hydroxide-silica complexes as they are not necessarily stable compounds) and they may be produced in either the gel or the sol state depending largely on the opal-alkali-water ratio.

It is only the gel form that causes significant expansion due to the swelling pressures exerted by such forms.

In addition to the above mortar-bar tests on sand-opal aggregates, the same aggregates were examined petrographically and by the accelerated chemical test.

The results of these tests carried out by the three aggregate-testing approaches available to this Division are summarised below:—

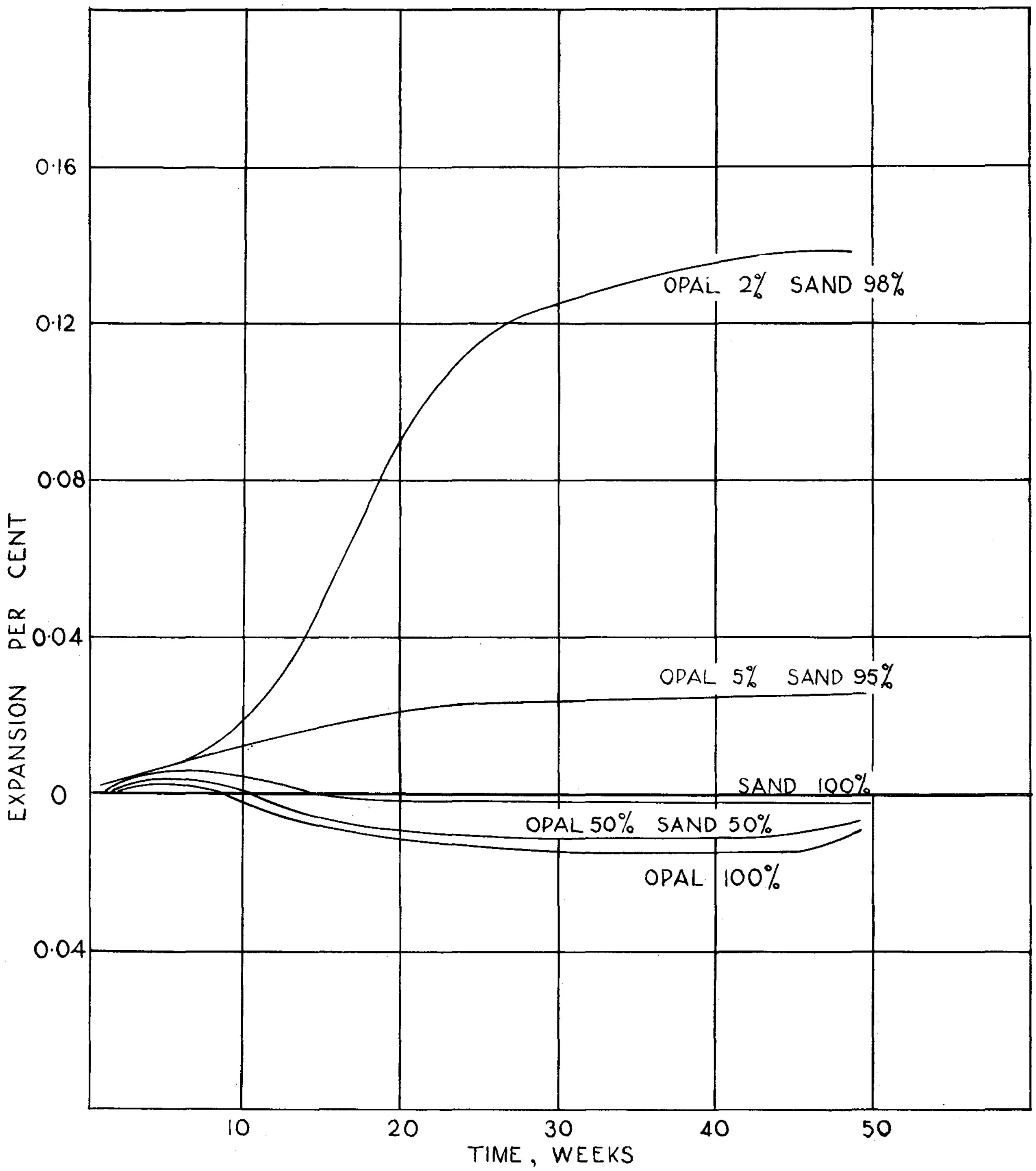
Aggregate	Classification by		
	Petrographic examination	Accelerated chemical test	Motar-ba test
100% sand	I	I	I
98% sand : 2% opal	R	R	R
95% sand : 5% opal	R	R*	I
50% sand : 50% opal	R	R*	I
100% opal	R	R*	I

I, innocuous; R, reactive.

* See text below.

An anomaly is apparent between the interpretation by the accelerated chemical test and by the mortar-bar test. The classification of an aggregate from the results of the chemical test depends on the magnitudes and ratio between the two factors determined, namely the reduction in alkalinity and the concentration of dissolved silica resulting from the reaction of the aggregate on an arbitrary alkaline solution.

Their position on a graph relative to a curve dividing innocuous from reactive materials is the basis for interpretation. However, it has been suggested, and the above results support the theory, that an additional curve can be drawn to define an area in which a normally reactive material is innocuous if it comprises the whole or a large proportion of the total aggregate. Interpreted on this basis, R* in the above table would be replaced by I.



EXPANSION OF SAND-OPAL MORTAR BARS

FIG 3

Petrographic examination aims primarily at proving or disproving the presence of minerals or rocks such as opal, tridymite, rhyolites and phyllites known to be reactive under certain conditions, and as opal was identified in four of the five samples no real anomaly exists here.

Other aggregates examined for Public Works Department included a coarse aggregate from Port Hedland. one coarse and two fine aggregates from Entrance Point, Broome, and a sand for general plaster work from Port Hedland.

Fifteen sands for the State Housing Commission through the Government Geologist were examined petrographically and tested for size distribution and organic matter content to determine their suitability for building purposes.

Complete petrographical and chemical examination of nine potential concrete aggregates from North West Cape were carried out at the request of the United States Navy.

Twenty-one aggregates, either as sands or broken rock, were examined for four different commercial interests.

One of these samples, from Norseman, contained about 16 per cent. of pyrite. Though not in a form generally accepted as reactive, such a high sulphide content in a concrete aggregate is to be avoided if at all possible. Other aggregates originated from Moora, Coomberdale, Esperance, Widgiemooltha and Cape Lambert.

(b) Miscellaneous.—Concrete water pipes from the Donnybrook Town Water Supply were examined at the request of the Public Works Department. A deposit on the inner surfaces was thought to indicate excessive corrosion of the pipes, but chemical and x-ray examination showed it to be an iron-rich compound deposited from solution or suspension. Corrosion was not excessive.

A cement floor topping was analysed at the request of Public Works Department to determine the cement content, while three mortars and two concretes were examined for private interests to determine the original mix.

The specific surface of four cement, or cement substitute, powders was measured at the request of a private company and a number of concrete samples were crushed and prepared for analysis by private firms and the Customs laboratory.

2. Lime.—Of eight lime samples examined on behalf of State Batteries four assayed higher than the specified minimum CaO figure (86 per cent.) on the ignited sample. Of those failing, the lowest was 83.3 per cent. and the others, though actually below, were reasonably close to the minimum.

One sample of burnt lime, submitted by private interests in Kalgoorlie, assayed 96.1 per cent free lime as received and 98 per cent. on the ignited sample.

Burnt limes were submitted for testing as to their suitability for use in regeneration of caustic soda for the alumina industry, but no figures were available from users to serve as commercial specifications.

Carbide sludges (the residue from acetylene generators) were examined, particularly for the presence of sulphur. One sample showed a total sulphur content of 0.09 per cent. about half of which was in the form of sulphate. A trace only of sulphide sulphur was detected.

Analytical assistance was given to the Engineering Chemistry Division in connection with their trials on the beneficiation of lime sands.

3. Miscellaneous.—Cause of cracking and "pop-out" in sand lime bricks was found to be due to inclusions which were originally a core of quicklime surrounded by a coating of slaked lime. Subsequent slaking of the quicklime during autoclaving caused stresses leading to cracks in the finished product.

At the request of the Public Works Department, discolouration of Donnybrook freestone being used in construction work at Parliament House was examined and found to be of vegetable origin. Its removal could be effected by treatment with bleaching powder.

The cause of dampness in an internal wall of a Kalgoorlie building was shown to be an excessive water-soluble salt content deriving from a period when the wall had no damp coursing.

The presence of pyrite and water-soluble salts was determined in three clays as part of an investigation by Engineering Chemistry Division into staining of cream clay bricks. The clays were also tested for vanadium, but with negative results.

The original mix of a lime:sand mortar was determined.

Clay

Assistance had been sought from the Department of Industrial Development by potential manufacturers for the establishment of brickworks at Carnarvon and Esperance. The Department accordingly submitted samples of the clays concerned for examination by this Division.

The clays from Carnarvon fell into two broad groups, depending on the salt content. The two low-salt (NaCl 0.06 per cent.) clays consisted of approximately equal parts of kaolinite, illite and a mixture of quartz, feldspar and mica. The illite was partially weathered to montmorillonite and some organic matter (total carbon 1.6 per cent.) was present. Burning tests indicated that a good brick could be produced at 950 deg. C., but above this temperature bloating developed rapidly, in fact the behaviour during firing was so critical that the clays could not be recommended for brick making.

In the high-salt (NaCl 0.6-0.9 per cent.) samples, illite made up about half of each sample, kaolinite a quarter and quartz, feldspar, mica, etc., the remainder. Total carbon was only about 0.2 per cent. Firing tests were carried out on these clays both in the "as received" state and after removal of most of the salt by washing.

Briquettes produced were satisfactory but close control of burning temperature would be necessary, though not so critical as in the first group. Removal of the salt resulted in a delay of about 100°C in the onset of distortion when fired not under load, and it also delayed the sudden undesirable collapse under load by a similar margin. Temperature control was thus less critical when firing the washed clay compared with the unwashed.

The two samples from Esperance submitted by Department of Industrial Development were mineralogically similar, both containing about 50 per cent. of kaolinite, the remainder being made up of quartz, calcite, magnetite, limonite and mica. Salt contents were 0.14 and 0.56 per cent. respectively, total carbon of the order of 0.3 per cent. Firing tests at temperatures between 950°C and 1250°C indicated that a satisfactory terra cotta brick could be obtained at temperatures in the vicinity of 1000°C but that at about 1100°C discoloration and blotching occur. Supplementary tests made by the Fuel Technology Division revealed an undesirable characteristic of one of these clays when fired under load in that it showed an initial shrinkage (up to 4.5 per cent) at low temperatures and then an expansion until it attained its original volume at about 1170°C. As it was felt that such clay might produce clinkered bricks and collapsed loads in the kiln its use was not recommended and preference was given to the second of the two samples.

In connection with their activities in the Narrows reclamation area the Main Roads Department submitted two samples of organic silty clay for determination of the nature and amount of the clay minerals present and the percentage of clay less than 2 microns in diameter. In one case the clay fraction was predominantly kaolinite with less than 10 per cent. illite; in the other, kaolinite, illite and montmorillonite were present in proportions approximating 3 : 3 : 1. Between a quarter and a third of each sample was finer than 2 microns.

Burning tests were carried out on a number of other clays submitted from various areas of the State. The most promising of these came from the Albany area. The predominantly kaolinitic clay was easy to work and gave an attractive pinkish buff briquette when fired at about 1050°C. The shrinkage at this temperature was only 1 per cent. and the resultant brick was tough and a little under steel hard. There was evidence of slight vanadium staining in briquettes that had been saturated with water and allowed to dry out.

An unusual clay from an undisclosed locality consisted of 30 per cent. montmorillonite, 10 per cent. kaolinite and 60 per cent. of a mixture of quartz and sponge spicules and minor amounts of nontronite, limonite and organic matter. As would be expected this clay showed excessive cracking and distortion on firing even at low temperatures.

For an industrial concern tests were made to compare the bonding strengths of different clays when compressed with their shale and fired at a series of temperatures between 900°C and 1200°C.

Other localities from which clay samples were sent for examination included Wiluna, Wagin, Mundaring and Gnowangerup. From the latter the clay was reported to occur in a 10 to 20 ft. layer about 100 ft. below ground level. The clay was identified as a montmorillonoid with marked swelling properties when wet. It was associated with a little quartz and mica.

During the year a Victorian firm was making enquiries regarding possible W.A. sources of clay suitable for coating paper. Requirements were for a white clay free from grit and having a reflectivity of at least 90 per cent. From our reference collection of W.A. clays we were able to select 14 samples having the required reflectivity, but unfortunately no geological information was available to assess the magnitude of the deposits from which they originated. C.S.I.R.O., were also interested in this enquiry and during a subsequent visit of an officer of that organisation to this State all samples of potential value for this particular use were made available for his examination.

A donation to the Mineral Division Collection was a parchment like material peeled from the walls of a cave in New Zealand. On examination it was found to be essentially attapulgite, a member of the palygorskite group of clay minerals and popularly known as "mountain leather."

A considerable number of chemical analyses for alkalies in clay was carried out to assist the Fuel Technologist in his work on the possible relationship between K_2O and Na_2O contents and the refractoriness of the clay when burnt under load, and its possible application as a light weight concrete aggregate after bloating.

Health Hazards

The Department of Public Health continued its investigation of industrial dust with the Division's Greenberg-Smith Impinger.

Siliceous and asbestos dust again received special attention.

Five samples of airborne dust were submitted for identification and particle count from the breathing zone of workers using carborundum discs for cutting masonry in a government building project. A used filter cartridge from a workman engaged in this project was also examined to determine the efficiency of the filter. Three specimens of the type of brick being cut were also chemically analysed to determine the free silica content.

A sample of airborne dust was submitted for identification and particle count from a dusty site at the works of a firm manufacturing clay products. A chemical analysis was made of dust settled on a ledge in the same site and also of seven samples of raw clay to determine free and combined silica.

Two samples of airborne dust were submitted from outside the blasting chamber of an engineering firm using steel grit blasting to clean metal products. A sample of the steel grit was also submitted for sizing and analysis for free silica and lead.

Six samples of airborne dust were submitted from the site at which workmen were using the Limpet process in which asbestos is sprayed on ceilings for insulation purposes.

Five samples of airborne dust were submitted from an engineering firm manufacturing a lagging compound composed of diatomite, clay and asbestos. A used respirator filter pad was also examined to assess its efficiency.

Two samples of airborne dust were submitted from a company milling talc, another material known to be harmful if inhaled in large amounts.

Two samples of flue dust from the stacks of a cement company alleged to be causing a local dust nuisance were examined microscopically and found to be largely calcium carbonate.

Nine samples of dust from the stacks were also examined microscopically as part of a study by the Fuel Technology Division for the Department of Labour to test the efficiency of aerodynamic dust arrestors installed in the stacks.

A total analysis was also done on two samples of the flue dust.

Throughout the year dust from deposition gauges that are regularly attended by the Fuel Technology Division were again examined fortnightly by a microscopist to determine composition of dust and grainsize.

Minerals and Ores

1. Beryl.—Though the overseas price of beryl showed practically no change throughout the year, its value to producers in Australia dropped by almost a third, to the vicinity of £9 per unit.

This may well account for the decrease in the number of samples submitted for examination from 76 in 1962 to 41 in 1963.

The 28 commercial parcels received averaged 11.5 per cent. BeO, extremes being 12.6 per cent. and 9.9 per cent.

2. Copper.—The continued interest in copper ores is reflected to some extent in the increased number of samples (149 in 1962, 211 in 1963) examined in this Division.

Buyers of fertiliser copper, after accepting 8 per cent. copper as a minimum grade for a number of years, have now raised this figure to 10 per cent. This has no doubt contributed something towards the increased activity in the beneficiation field.

A considerable percentage of the copper ores examined are analysed for both total copper and acetic acid-soluble copper, the latter being a measure of the copper readily available to plants. Others are analysed for gold and silver as well as copper.

High-grade specimens and samples were received from a wide range of localities from the Kimberleys to the South West. Many were remarkable for the variety of copper minerals present. One, from near Roebourne, contained malachite, chalcocite, chalcopyrite, brochantite, cuprite, digenite and covellite and assayed 38.7 per cent. total copper, with 32.2 per cent. in the acetic acid-soluble form. Beside representing a new localtiy for brochantite this sample was the first in which digenite was positively identified in this State. It is a cuprous sulphide slightly deficient in copper compared with the better known sulphide chalcocite (Cu_2S) and has a composition varying from $Cu_{1.5}S$ to $Cu_{1.9}S$. It has subsequently been identified in other samples from Gabanintha, Ravensthorpe, and Glenburgh Station, in the latter associated with pyrite, chalcopyrite and blende.

Another sample, from Gabanintha, contained malachite, tenorite, chalcocite, covellite and chalcopyrite as well as appreciable concentrations of gold and silver. Bornite was also reported from Gabanintha.

A speciment from Mt. Amherst, in the Kimberley Division, was the first occurrence of copper minerals recorded by us in this locality. It assayed 46.7 per cent. copper and was predominantly malachite, with tenorite, chalcocite, covellite and cuprite also present.

A high-grade specimen from North Pole, 25 miles west of Marble Bar, contained the only native copper received during the year. A sample from Mabel Downs Station, East Kimberley, was essentially magnetite, assaying 54.7 per cent. iron but contained also 5.15 per cent. copper as malachite.

A sample from Dalgety Downs provided the first recorded occurrence of brochantite in the Murchison Division.

Of other copper minerals, atacamite was present with cuprite and malachite in a sample from Uaroo Station. Chrysocolla occurred in a fine-grained quartz to the extent of about 25 per cent., but was so intimately associated with the quartz that at 90 mesh only about a third of the total copper content was recoverable by solution in acetic acid.

Thirteen samples from a Warriedar copper mine were assayed for the State Mining Engineer and 16 diamond drill cores were assayed in connection with a prospecting programme undertaken by a mining company.

Assistance was given to a client interested in acid-leaching of oxidised copper ores for the production of copper sulphate. Analyses and experiments carried out provided data to assess the economics of small scale production.

3. Gold and Silver.—Commercial laboratories at present handling large numbers of routine samples from the numerous mining organisations now active in geological exploration are not equipped for fire assaying. As a result, an increased number of pay assays for gold and silver were carried out by this Division at the request of these industrial laboratories.

Of the pay samples submitted for fire assay an unusually large proportion were for silver determination in addition to gold.

A normal quota of free assays for prospectors, as well as check and umpire assays for State Batteries was received during the year.

An examination of gold-bearing ore from a Bamboo Creek mine was undertaken at the request of the Government Geologist. The ore was being crushed at the Marble Bar State Battery, but recovery over the plates and by cyanidation was very poor.

The rock was composed of fine-grained mica, quartz and ankerite cut by quartz veins. Mineralisation consisted of coarse segregations of wolframite, veinlets of pyrite and fine-grained disseminated needles of arsenopyrite. The pyrite and arsenopyrite crystals both contained traces of visible gold up to 10 microns in diameter.

The rock was fractionated into micaceous, siliceous and micaceous-carbonate fractions, all showing some degree of mineralisation. Assays of these fractions showed that over 80 per cent. of the gold was associated with the micaceous portion which comprised about a third of the total sample. Even after extremely fine grinding there was still a high proportion of composite sulphide-mica particles and it was apparent that much of the gold would still resist amalgamation and cyanidation. It was concluded that calcination was the most likely method of freeing the gold.

4.—Gypsum.—The number of gypsum samples received was between four and five times as great as in the previous year. This is largely the result of a campaign by interested parties to sell gypsum to farmers for agricultural uses. The Department of Agriculture states that it has no evidence to suggest that gypsum as such serves any nutritional purpose as a fertilizer on most W.A. soils. Any suggestion that it can be used as a substitute for superphosphate is of course completely without foundation.

High grade material was received from a number of localities, including Cliff Head, Lake King, Kalannie and Hopetoun areas. It ranged in sizing from fine flour to coarse crystals. Commercial development of the Cliff Head deposit 25 miles south of Dongara has been reported.

5. Heavy Sands.—With the exception of a sample from Turkey Creek Station in the Kimberleys, all heavy sands originated from the South West Division.

Samples from inland areas came from Newdegate, Moojebing and Bencubbin in all of which the predominating heavy mineral was ilmenite.

A sample from Midland contained 47 per cent. ilmenite, 13 per cent. zircon and 3 per cent. rutile with traces of monazite, while in others from Kalgan River and Pinjarra, ilmenite was by far the predominant heavy mineral.

In a sample from Kirup the small (4 per cent.) heavy mineral fraction was composed of sillimanite and tourmaline.

From coastal localities such as Augusta, Hamelin Bay and Hopetoun, ilmenite was the main heavy mineral.

A batch of 18 samples from the flank of the Darling Range, south of Byford, was examined for the Geological Survey, These varied from 46 per cent. of heavy minerals down to less than 1 per cent. ilmenite being the predominant mineral with leucoxene, zircon and rutile being also present.

6. Iron.—With private interests undertaking much of the iron exploration work the number of iron samples submitted to these Laboratories from Departmental sources has declined. Routine analysis of large batches of samples for private mining companies is undertaken by commercial laboratories in Perth and are handled by the Government Laboratories only in special circumstances.

Complete analysies of Robe River ores were carried out on material being used by Engineering Chemistry Division in an iron ore beneficiation investigation.

A number of specimens from the Brockman banded iron formations of the Wittenoom area were examined for Geological Survey of Western Australia to assess the possibilty of approximate iron estimations in the field based on specific gravity of rock specimens. The rocks showed an unexpected but variable degree of porosity, those with higher iron content showing the higher porosity. This was manifest by the difference in gravities of the rocks in their pulverised and uncrushed forms.

The minerals present were primarily hematite, limonite, magnetite, goethite and quartz. The proportions of these minerals were calculated from the analysis of the specimens for ferrous and ferric iron, silica and combined water and the theoretical gravity of the composite rock calculated. These calculated gravities showed quite close agreement with the measured gravities of the pulverised rocks as shown in the following table.

Iron content	Specific gravity		
	Uncrushed	Pulverised	Calculated
%			
56·7	3·54	4·03	4·12
45·3	3·43	3·59	3·64
23·8	2·99	3·09	3·10
9·0	2·77	2·79	2·79

Plotting iron content against pulverised gravity gives a smooth curve but owing to the necessity for pulverising and the resultant complications in gravity determination the method does not appear satisfactory for field application.

Four attractively polished iron ore specimens were displayed by the Department of Industrial Development at the Sydney Trade Fair held during the year. The Division was asked to identify the component minerals and suggest an iron assay figure without damaging the specimens, two of which were from the famous Mesabi Range deposits of Minnesota and two from the W.A. Hamersley Ranges. Samples were taken from the unpolished surfaces for assay and X-ray determination of the minerals present.

Most of the analytical work on iron ores was at the request of Geological Survey of Western Australia. From the Hamersley Ranges, 88 iron determinations were made with virtually complete analyses of 8 composites from the same suite. Other localities from which samples were received included Mt. Gibson and Pompey's Pillar.

Iron minerals examined included a striking goethite specimen from Doomeday Hill near Nullagine, sent in by the Department of Native Welfare, a hematite from the Avon Valley assaying 69.4 per cent. iron, two martite samples from Gwalia and Trilbar Station, the latter assaying 64.9 per cent. and stilpnomelane identified in some of the banded iron formations at Wittenoom.

A titanium—bearing magnetite from Coates Siding assayed 0.45 per cent. vanadium pentoxide and a hematite from Gabanintha, intergrown with ilmenite, showed 1.05 per cent. V_2O_5. In neither of these samples was it possible to isolate coulsonite or any other specific vanadium mineral.

7. Limestone and Limesand.—Most of the work under this heading was in conjunction with work being carried out by Engineering Chemistry Division on the beneficiation of lime sands, though a batch of 19 samples from Garden Island was graded at the request of a mining company.

A sample of limestone from the Wanneroo area, consisting largely of crytalline calcite, was markedly different from the usual coastal limestone.

Of interest among the calciun carbonate minerals examined were a black calcite from the Roebourne area, a fibrous aragonite from Napier Downs Station in the Kimberleys and a set of minerals from caves in the South West corner of the State. These latter were mainly stalactitic and included typical "dog tooth spar," "Mexican onyx" and other crystalline forms.

A micro-determination for carbonate mineral was carried out at the rquest of the Geological Survey. A gas evolution method was adopted and showed a carbon dioxide content of 110 parts per million.

8. Lithium.—Perhaps the most interesting lithium minerals examined during the year were those belonging to the phosphate group typified by lithiophilite. A sample from Wodgina consisted of lithiophilite with a range of alteration products, chief of which was a dark brown sicklerite, but with traces also of purpurite, hureaulite and possibly the sodium manganese iron phosphate, alluaudite.

Graftonite, an iron manganese calcium phosphate, was identified for the first time in this State in a lithiophilite sample from Yinnietharra. Ferrisicklerite was also present in this specimen.

Spodumene contaminated with quartz and feldspar was received from a recently discovered locality in the Roebourne district. The cleanest sample assayed 4.26 per cent. lithia (Li_2O).

Particularly good specimens of spodumene have been obtained since the opening up of the Catlin Creek pegmatite at Ravensthorpe by commercial mining interests. Specimens of montebrasite from the same locality were also identified.

Twelve lithium-bearing ores from Poona were examined and the only lithium mineral identified was lepidolite. Even the richest, assaying 2.74 per cent. Li_2O, would require up-grading to reach the minimum marketable Li_2O concentration of 3.5 per cent.

A lithium-bearing muscovite from Warda Warra assayed 2.35 per cent. Li_2O while eight samples submitted by a mining company showed lithia figures from 0.24 per cent. up to 4.28 per cent. the lithium minerals present being petalite, zinnwaldite, lepidolite and spodumene.

A lithium mineral recorded for the first time in W.A. was eucryptite. This is one of the major lithium bearing minerals of the famous Bikita pegmatites of Southern Rhodesia and though mined there at the rate of several hundred tons per year, is very rare in other parts of the world. The W.A. occurrence is at Londonderry where it occurs as pink mineral in close association with the more common petalite.

Cookeite, an uncommon lithium aluminium silicate having a micaceous cleavage, was identified associated with prehnite in pegmatite samples from Londonderry.

A hand picked specimen assayed 3.68 per cent. Li_2O.

9. Tantalo—Columbate Minerals.—Prices on offer for these minerals dropped drastically during the second half of the year. Nevertheless, the Division was called on to grade and analyse a considerable number of commercial parcels.

Though many were reasonably clean tantalite-columbite concentrates others were much too complex for simple grading. Among the latter may be mentioned a tapiolite partially altered to microlite, a tantalite with microlite-tapiolite intergrowths, tantalite and microlite in intimate association and a parcel containing approximately 21 per cent. cassiterite, 40 per cent. of a pyrochlore-microlite intergrowth, and 34 per cent. of columbo-tantalite, pyrochlore-microlite mixture.

As in the past, parcels were received in which there was no relationship between the cassiterite content and the total SnO_2 as obtained chemically. One such originating from the North-West, was composed of 96 per cent. tantalite, 3 per cent. cassiterite, 1 per cent. sundries and yet assayed 6.46 per cent. SnO_2.

Stannotantalite a recently identified variety of tantalite, has been described from U.S.S.R. ("New Data of Rare Element Mineralogy", Consultants Bureau, N.Y. 1963) and it is possible that this mineral occurs in W.A., but has not yet been isolated. Its presence in commercial parcels would account for the tin discrepancies mentioned above.

Tantalite in seven ores containing only a few ounces of the mineral per ton was determined by heavy liquid and electromagnetic techniques at the request of an exploration syndicate.

Eight samples, varying from low grade ore to rough concentrates were analysed for niobium, tantalum, tin and tungsten for a mining company examining the Dalgaranga deposits.

Requests for tantalum and niobium assays from Darwin, and for tantalum, niobium and tin determinations from the Department of Geophysics, Australian National University, were met by the Division.

A parcel from the Pilbara fields containing 26 per cent. of cassiterite consisted for the most part of a mixture of metamict tantalum-niobium minerals and their alteration products. No tantalite or columbite was present, but the minerals identified or strongly suspected included microlite, members of the fergusonite-formanite series, annerodite, samarskite and tanteuxenite. Though a closer study of concentrates of this nature could be most informative it was not possible to release the necessary staff from more urgent matters.

A specimen from Cooglegong, S.G. 6.688, was identified from the x-ray diffraction patterns obtained before and after ignition as the metamict rare-earth columbo-tantalate formanite.

10. Tin.—The considerable increase in tin samples received was due largely to the extensive sampling programme being undertaken commercially on the Greenbushes tin field. All samples from this source were analysed for tantalum and niobium as well as tin and consisted mainly of concentrates and various electromagnetic fractions.

Other samples handled included sales parcels of cassiterite concentrates, tin ores, and products from various stages of concentration flowsheets. Many were examined mineralogically as well as chemically.

The Division was able to supply the University Department of Physics with cassiterite specimens from a large number of different sources. The specimens were required to extend the Department's study of the relative abundance of the isotopes of tin.

During the year attention was drawn to the difference in tin figures obtained on the same sample by different laboratories. With the price of tin in excess of £1,300 per ton a difference of 0.1 per cent. in analytical figures on a cassiterite concentrate is of economic significance. In order to compare methods of anlysis and if possible to determine the degree of agreement which may reasonably be expected in figures from different laboratories, a programme was organised whereby two tin samples were distributed between 10 laboratories for check assays. The co-operating laboratories were—

Australian Mineral Development Laboratories, Adelaide.
Department of Geological Survey, Ipoh, Malaya.
Department of Mines, Ipoh, Malaya.
Department of Mines, Launceston, Tasmania.
Government Chemical Laboratories, Perth.
Matthey Garret Pty. Ltd., Sydney.
Overseas Geological Survey, London.
Straits Trading Co. Pty. Ltd., Penang, Malaya.
Straits Trading Co. Pty. Ltd., Pulau Brani, Malaya.
Sydney Smelting Co. Pty. Ltd., Sydney.

The figures obtained are tabulated below, the laboratory numbers bearing no relationship to the above alphabetical list.

Laboratory	Sample A	Sample B
	Tin, Sn % on dry basis	Tin, Sn % on dry basis
1	63·2	66·0
2	63·9	66·45
3	63·5	66·3
4	63·30	65·88
5	63·61	66·34
6	63·21	66·10
7	63·24	66·15
8	63·37	66·36
9	63·68	66·38
10	63·61	66·39
Average	63·46	66·24

The following table further summarises relevant data:—

Laboratory	Nature	Sample A	Sample B	Analytical method
		Departure from average	Departure from average	
1	C	—0·26	—0·24	Gravimetric
2	NC	+0·44	+0·21	X-Ray fluorescence
3	C	+0·04	+0·06	Gravimetric
4	NC	—0·16	—0·36	Volumetric
5	NC	+0·15	+0·10	Volumetric
6	NC	—0·25	—0·14	Volumetric
7	NC	—0·22	—0·09	Volumetric
8	C	—0·09	+0·12	Volumetric
9	NC	+0·22	+0·14	Volumetric
10	C	+0·15	+0·15	Volumetric

C commercial, NC non-commercial.

The gravimetric method is initiated by a fusion of the sample with cyanide and direct weighing of the metallic tin. Though volumetric methods were the most widely used there were a number of variants of this method depending on preliminary treatment, method of attack (Na_2O_2 fusion or gaseous reduction), reductant used (Al or Ni), titrant used (KIO_3 or Iodine) and KI concentration in titrant.

A study of these results, in conjunction with details of the methods used, showed a remarkably even distribution of positive and negative error between the different methods of assay and the different types of laboratories involved.

The overall conclusion drawn is that variations of the order of ±0.2 per cent. occur in the tin figures reported on tin concentrates by different laboratories.

Miscellaneous Analyses.

1. Mineral.—Complete analyses of seven silicate rocks from the Dixon Range area of the Kimberleys were carried out for Geological Survey.

None of the *chromite* samples examined represented high-grade material, the highest chromium: iron ratio being about 1.1:1. This one originated from 15 miles SE of Byro Station homestead, and assayed 28.5 per cent. chromium. One of approximately similar grade came from the Panton River in the Kimberleys. Chromite-magnetite intergrowths from the Murchison assayed between 15 and 20 per cent. chromium, with about double that amount of iron.

A number of *dolomite* samples were analysed and some proved of high grade. One from Kulin, with a $MgCO_3$:$CaCO_3$ ratio of 3.8:1 contained less than 0.3 per cent. acid insoluble material, whereas a number from the Ravensthorpe area contained between 7 and 16 per cent. silica. A sample from White Springs in the Pilbara assayed 43.5 per cent. $MgCO_3$ and 55.7 per cent. $CaCO_3$.

Magnesite from Dandalup Creek contained 0.34 per cent. silica and 3.25 per cent. $CaCO_3$.

A sample from near Mt. Leopold, between Roebourne and Onslow, was found to be composed essentially of *diaspore* and *pyrophyllite*. As high-alumina minerals are imported into W.A. (for example, andalusite from South Africa) the above material could be regarded as an alternative local source.

As the following analysis shows, its alumina content is considerably in excess of that of andalusite.

	Per Cent.
Alumina, Al_2O_3	61.7
Silica, SiO_2	23.8
Combined water, H_2O^+	11.1
Titanium dioxide, TiO_2	2.53
Iron oxide, Fe_2O_3	0.81
Phosphorus pentoxide, P_2O_5	0.11

Lime, magnesia and manganese oxide were not detected.

The above figures, considered in conjunction with x-ray data, suggest the following mineral composition:—

Diaspore, Al_2O_3. H_2O	60.7
Pyrophyllite, Al_2O_3. $4SiO_2$. H_2O	35.7

A number of *bauxite* samples were analysed for soda-soluble alumina and silica, and *salt* samples were analysed at the request of both producers and consumers.

A range of minerals and rocks was analysed for other elements, including nickel, vanadium, tungsten, zinc, arsenic, antimony, lead, rare-earths and phosphorus.

A sample of interest was received from near the Mt. Vernon homestead. It consisted of a fibrous bluish-white mineral with a white crust. The white crust was separated and both fractions were analysed with the results shown below.

	White	Bluish-white
	Per Cent.	
Alumina, Al_2O_3	0.95	8.58
Magnesia, MgO	15.90	8.59
Lime, CaO	0.43	0.10
Soda, Na_2O	0.33	0.18
Potash, K_2O	0.22	0.11
*Water, H_2O^+	49.07	43.31
Sulphur trioxide, SO_3	31.60	35.40
Chlorine, Cl	1.03	3.32
Copper oxide, CuO	0.35	0.35
Manganese oxide, MnO	trace	trace
Zinc oxide, ZnO	0.12	0.06

* by difference.

Each fraction was water-soluble. The minerals present were shown to be essentially pickeringite and epsomite. The analytical figures indicate that the white crust is epsomite, $MgSO_4$. $7H_2O$ and that the bluish-white fraction is a mixture of epsomite and pickeringite $MgSO_4.Al_2(SO_4)_3$. $22H_2O$ in a ratio approximating 3 epsomite to 7 pickeringite.

2. Alloys.—At the request of Department of Industrial Development a number of cast-iron ingots were sampled and analysed for carbon and silicon content. This was in connection with experiments aimed at the production of cast iron from steel, as opposed to iron scrap.

Five samples of mild steel reinforcing rod were assayed for carbon. A sample of cast mild steel turnings was analysed at the request of a commercial firm who were obtaining results for the sulphur content varying with the analytical method used.

The Division confirmed that this was so, a sulphur content of 0.063 per cent. being obtained by a gravimetric method and one of 0.049 by the evolution method. These figures were in agreement with those obtained by the firm and indicated that some of the sulphur in the steel was in a form that would not evolve sulphuretted hydrogen under the standardised conditions of the evolution method.

Lead samples were examined for the Metropolitan Water Supply, Sewerage and Drainage Department and samples of dross, solder and scrap were analysed for zinc, aluminium, tin, lead and antimony.

Eleven magnesium-aluminium alloys were analysed for the University in connection with an investigation by the Physics Department of the soft x-ray spectra of these alloys.

A number of galvanised metal parts were examined for the weight, uniformity, smoothness, continuity and staining of the zinc coating while for the Department of Civil Aviation a plated wire was found to be coated with tin, not cadmium as expected.

Other work on metallic coatings included a study of the thickness and uniformity of the anodic coating on extruded aluminium parts. These properties were determined microscopically and photomicrographs of typical cross sections were prepared.

A sample consisting of 5 milligrams of metal filings was submitted for examination by the Criminal Investigation Branch. The particle size and composition were determined by chemical and x-ray diffraction techniques, and photomicrographs were supplied to the Police.

A cannon ball from an unidentified wreck was examined at the request of the W.A. Museum and found to consist largely of goethite with concentric rings of magnetite.

Mineral Identifications.

1. Miscellaneous.—Many mineral identifications are described under appropriate headings throughout this report. This section refers to a selection not elsewhere described.

Among the *epidote* specimens examined was a spectacular sample from the Derby area in which the epidote occurred as a rosette in crystalline quartz. Epidote, in association was quartz, feldspar, pyrite and sphene came from the vicinity of Canning Weir while other striking specimens were found at Cranbrook, Dardanup and Lake Grace. A particularly ornamental rock from Mangaroon Station was comprised mainly of garnet and epidote.

An unusual from of *garnet* was received from Comet Vale. It was black in hand specimens, and associated with quartz, chlorite and limonite. It was yellow-pink in thin section, birefrigent with R.I. about 1.85. The x-ray diffraction pattern was similar to that of grossularite, but the R.I. was abnormally high. Chemical work will be put in hand to determine its species, which will probably be either grossularite or andradite.

The relatively uncommon *andradite* was identified in specimens from Shaw River: it was isotropic with R.I. about 1.88 and S.G. 3.6.

Massive garnet, as well as a fine individual crystal about 2½" across, originated from Donnybrook.

From the amphibole family, a number of specimens from the *tremolite-actinolite* series were examined. Fibrous tremolite, with long but brittle fibres came from 9 miles east of Roebourne. The same abestiform mineral from Yalgoo and Richenda (Kimberley) likewise showed poor fibre strength. Partly silicified forms were received from Mt. Seabrook and Gabanintha. A striking specimen from Yandeyarra in the Port Hedland area was composed of dark green actinolite and light green asbestiform *anthophyllite.*

Anthophyllite was also received from Payne's Find and associated with *cummingtonite,* actinolite and biotite from Dowerin.

An appreciable amount of *sillimanite* was present in a sand from Kirup.

Fuchsite from Coordenwandy had rutile inclusions. Clear but flawed pink sheets of *muscovite* came from Kalgoorlie, with rather larger sheets, but still not of commercial quality from Kirup. A poor quality *vermiculite* came from between Collie and Bunbury.

The dark green chlorite *thuringite* was identified in lode material from a Kalgoorlie mine.

Prehnite was identified as thin films lining fracture surfaces of a coarsely crystallised hornblende-feldspar rock from 15 miles N.W. of Norseman, and in association with cookeite in the Londonderry pegmatites.

Zoned *tourmaline* specimens were collected from the Catlin Creek pegmatites and from 15 miles N.W. of Norseman. These were mostly blue-green in the outer zones and pink in the inner.

Feldspars examined included a *microcline* from 25 m. North of Geraldton containing small inclusions of graphite and an ornamental green microcline from Payne's Find.

Other pegmatite minerals included *rubellite,* massive fine-grained *mica, zinnwaldite, spodumene* and *blende* from Catlin Creek, Ravensthorpe, *bityite* and *bavenite* from Londonderry. and *topaz* from Yandeyarra.

Red brown fragments of flame *opal* came from the Gwalia district. Carefully cut it would no doubt make attractive trinkets, but similar material cut in these Laboratories several years ago, though brilliant and flawless when cut, developed many cracks in the following two or three years, probably due to gradual dehydration of the silica. "Scenic" opal from Byro, which has been on the market in the form of trinkets for about two years now, has not been reported as suffering from this defect.

A specimen stated to have been found near Nullagine was examined and found to be *diamond.*

Three specimens of *bismuth* bearing minerals were obtained. All were carbonates and associated in varying degrees with quartz and feldspar. One locality was too vague to be of value; the remaining two samples originated from Yinnietharra and Talga Talga.

Baryte from Belele Station crushed to an off-white powder due to minor amounts of limonite staining, but one from Dalgaranga was high-grade material with only very minor superficial staining. A typical specimen of South Australian commercial baryte was received for addition to our reference mineral collection.

An uncommon form of *dolomite* was received from a mile west of L. Ballard. It consisted of elongated crystals of iron-bearing dolomite thinly coated by vermiculite. With the iron content equivalent to only about 6 per cent. $FeCO_3$ it could not be described as ankerite, but is perhaps best classified as ferroan dolomite.

An interesting specimen was received from ten miles north of the Nanutarra Station homestead in the Onslow district. Its x-ray diffraction pattern showed the rutile structure, but with slightly larger cell, and its specific gravity of 4.7 was higher than normal rutile. As well as titanium, it contained appreciable amounts of iron, tantalum and niobium and, in the absence of a complete chemical analysis, could probably best be described as *ilmenorutile* or niobian rutile.

A porous mass of hydrous manganese and iron oxides, clay minerals, quartz and organic matter from the extreme South West assayed 24.1 per cent. manganese and 12.4 per cent. iron. It had originated most probably from precipitation of iron and manganese under swampy conditions, where both chemical and bacterial action would operate.

Oddly shaped concretions from the 40 mile peg on the Broome-Derby road consisted of goethite, hematite and quartz.

Other minerals received include *nontronite* from Mt. Seabrook, *cryptomelane* from Roebourne, *stibnite* from Youanmi, *monazite* from the Pilbara, *chalybite* and *corundum* from the Nullagine area and *ankerite* from Gabanintha.

An opportunity was found during the year to make a preliminary study of a rare Broken Hill mineral that had been donated to the Division by a company geologist. The mineral was *inesite*, a hydrated calcium manganese silicate which is reported to occur in spectacular masses in vughs in one of the Broken Hill Mines.

Minerals associated with the inesite in this specimen include calcite, quartz, a black hydrous manganese iron silicate, and traces of galena and sphalerite, the last two forming microscopic particles in the black silicate.

The inesite was identified by its optical and chemical properties and x-ray powder patterns which closely match those of inesite from Sweden. However though d/n values reported in the ASTM Powder Data File No. 12-177 are close to those of the Swedish and Australian inesites, the intensities of many of the lines vary considerably.

W. E. Richmond (Amer. Min. 27, p. 563) has suggested that dehydrated inesite is similar to calcium-rich rhodonite, but with lower refractive indices. His indices for dehydrated inesite however, are close to those for bustamite (Ca Mn) SiO_3, and x-ray and optical data for the Australian and Swedish inesite heated to 850°C for 5-6 hours in nitrogen match those for bustamite.

2. New Localities.—New localities recorded during the year were mainly in the North West Division.

In the majority of cases we are dependent on the description of the locality as supplied to us by the finders. It is obvious that few of these would be equipped for accurate surveying.

Minerals for which new occurrences were recorded in 1963 are listed below.

Mineral.	New Locality.
	(a) Kimberley Division.
Malachite, Tenorite, Chalcocite, Covellite, Cuprite	4m. North of Mt. Amherst.
Aragonite	1m. South of Napier Downs Homestead.
	(b) North West Division.
Malachite	12m. South West of Lyndon Homestead.
Native copper	Breen's North Pole.
Brochantite	Roebourne.
Digenite	5m. South of Roebourne.
Graftonite	Yinnietharra.
Celestite	2½m. South of Comet Mine, Marble Bar.
Ilmenite (massive)	Yinnietharra.
Jarosite	Near Mt. Vernon Homestead.
Variscite	Near Mt. Vernon Homestead.
Paratacamite	Near Mt. Vernon Homestead.
Cryptomelane	9m. West of Roebourne.
	(c) Murchison Division.
Chromite	Mt. Seabrook.
Chromite	30m. West of Wooleen Homestead.
Brochantite	Boundary of Dalgety Downs - Glenburgh Stations.
Digenite	4m. South East of Gabanintha.
	(d) Central.
Eucryptite	Londonderry.
	(e) South West.
Tantalite	Mt. Edon.
Fluorite	Catlin Creek, Ravensthorpe.
Digenite	Ravensthorpe.
Freirinite	Ravensthorpe and Kundip.
Prehnite	Ravensthorpe.
	(f) Eucla.
Stilbite	Norseman.

3. Spurious Minerals.—A speiss containing iron, sulphur, arsenic and traces of copper and antimony was sent in from Gooseberry Hill for identification.

A piece of silicon was found on a metropolitan beach. It was typical of the material used in the metallurgical industry, as was the specimen of ferro-manganese found at Fremantle.

A black glassy isotropic material of low fusibility from Mt. Edon proved to be a form of slag.

Bituminous materials collected from the Nannup-Bridgetown Road and from the mouth of the Fitzgerald River were submitted for examination.

4. Fossils.—A specimen of silicified wood from 30 miles south of Norseman showed well preserved internal and external detail.

A type of spongolite from Mt. Edward, 8 miles east of Esperance, was predominantly granular opal with sponge spicules, quartz, mica and clay. It contained fossil impressions of the pectinacean, bryozoan, coral and gastropod groups.

Fossil sponge was identified in a sample of spongolite from Ravensthorpe.

The Geological Survey submitted a dense siltstone forming the cap of Mt. Brooking in the Kimberleys which showed some unusual structures not unlike fossils. In cross section the structures were lens-shaped. In plan they were roughly circular, varying from ¼ in. to 1 in. in diameter, showing white radial lines running to a white periphery. The white material was composed of kaolin and fine-grained quartz, but sufficient evidence was not available to decide whether the structures were of organic or inorganic origin, though the former seems the more likely.

Miscellaneous

The U.S. Navy is conducting an investigation on corrosion resistance of various metals in soils of the North West Cape VLF site. Results of these studies aid in selecting suitable materials for underground use, in determining the extent of galvanic corrosion, in developing methods of protection and other related factors. At the request of the Navy, the Mineral Division has contributed to this programme by reporting on the nature and extent of the corrosion on a large number of test pieces submitted and on the chemical and mineralogical identity of the various corrosion products.

Two samples of diamond drill cores were examined at the request of a mining company to obtain data that might help compare their drilling characteristics. Petrographic, x-ray and chemical work gave figures comparing the relative amounts of the two main constituents, namely quartz and chlorite, in the sample.

PHYSICS AND PYROMETRY SECTION

The work of the section may be described under three headings. The pyrometry work now consists of laboratory comparison of thermometers and thermocouples for the general public to the highest degree of accuracy available in the State. Signatories for the issue of NATA certificates for such work are N. L. Marsh and R. P. Donnelly.

Developmental, research, and routine analytical work is covered under the headings Differential Thermal Analysis and X-ray Methods.

Pyrometry

Certificates of test for a total of 16 mercury in glass solid stem thermometers were issued for the year. The total range covered was from ice point to 320°C using oil and water baths for comparison of the thermometers under the test with the laboratory sub-standards. Accuracies quoted ranged from ±0.05°C to ±1°C. Certificates were also issued for calibration of three thermocouples with their associated temperature indicators.

Differential Thermal Analysis

Failure of the internally wound furnace early in the year due to insufficient anchoring of the heating element necessitated obtaining a commercial furnace of more robust construction. However, due to delay in supply from Europe the furnace is only now in the process of assembly. Work will commence as soon as possible on studies of lightweight aggregates and thermal reduction of iron in ilmenite.

X-ray Methods

(1)) X-ray Fluorescence.—Investigation of a simple method of non-dispersive X-ray fluorescence analysis (Nature 196(4858), 984, Dec. 62) was begun midway through the year. Metal foil x-ray filters and a sensitive geiger counter have been obtained from the United Kingdom and the method is being tested for application to mineral and other anlyses. However, lack of space and staff means that full attention cannot be given to any one project at a time and hence progress is often slow.

(2) X-ray Diffraction.—A numerical total of 116 samples was examined by powder diffraction. This work was carried out by the Physicist and three Mineralogists from the Mineral Division. Some examples of the work done by the Section are given below.

(a) Three microlites from the mineral collections were examined by X-ray powder diffraction. A Czechoslovakian enquiry to the Geological Survey of W.A. had resulted from an account of a stibiomicrolite in a previous Annual Report, for 1952. Since the only relevant mineralogical reference known to us is that quoted by Dana, Vol. 1, 7th Ed. supposing stibiomicrolite to be a "hypothetical mineral inferred from its disintegration products . . . " it was thought advisable to re-examine some microlite specimens including a sample from near the locality referred to in the above report. This had been shown chemically to be a bismuth bearing calcium antimony tantalate, which was isotropic with a high refractive index. Results of the X-ray examination were as follows: Powder patterns of an analysed microlite. an analysed stibian microlite and the bismuth bearing stibian microlite in question were very similar and could only be distinguished with difficulty. This shows (i) that antimony bearing microlite (stibiomicrolite) has the same structure as true microlite and can be regarded as due to an isomorphous substitution of Sb for Ca; and (ii) that the bismuth bearing stibiomicrolite also has the same structure. Further chemical work will be done to determine the composition of this mineral.

The above samples were further tested by ignition at 1200 deg. C. after fine grinding. X-ray powder patterns of the products showed similar reactions to have taken place, but that there were more apparent differences in patterns of the heated material than in the original patterns. The thermal recrystallisation products of microlite appear to be—

(i) a cubic phase 3.9Å;
(ii) a phase resembling yttrotantalite;
(iii) an unknown.

The nature of such thermal transformations remains to be studied. It appears that the product patterns may be more indicative of the mineral's chemical composition than the raw pattern and so this method of identification may obviate the need for chemical analysis in cases where a rapid estimate of composition is needed.

(b) Further work on a sample sent in by the School of Mines, Kalgoorlie, was required to discover the source of tellurium in the sample. The material was in the form of a crushed gravity concentrate and attempts to further concentrate the tellurium mineral were unsuccessful. Optical examination showed that discrete telluride grains were present but their small size (less than 200 mesh) precluded definite identification. After considerable effort one of these grains produced a pattern which was shown to be due to a mixture of altaite and hessite. It is probable that other telluride minerals are also present in the sample.

(c) A specimen recovered from the wreck thought to be the Gilt Dragon was shown to be identical with litharge. An alteration product associated with the litharge could not be identified.

(d) A pegmatite phosphate mineral graftonite occurring with ferrisicklerite was identified by x-ray diffraction since optical identification in this case is difficult. Other minerals in minute amounts are also present in this specimen including one not identifiable from the x-ray Powder Data File.

(e) Two specimens were collected from MC34 Ravensthorpe as typical examples of coballite ores with blue surface coating of a hydrous copper arsenate long thought to be olivenite. Re-examination of the so-called olivenite showed it to have the x-ray pattern of freirinite, a hydrous sodium copper arsenate, the first recorded occurrence in W.A. Subsequent x-ray patterns showed some collection specimens from Ravensthorpe labelled olivenite to be freirinite.

(f) A sample suspected of being a diamond was about the size of a grain of wheat, and tests had to be carried out without destroying any of the material. Physical and optical examination showed that the grain was indeed diamond but the final conclusive proof was obtained by taking an x-ray diffraction pattern which showed that the grain was not a single crystal but an aggregate of diamond crystals.

(g) One of a group of specimens from Mt. Vernon Station collected by an officer of the Geological Survey of W.A. consisted of a phosphatic sandstone with surface stains of a copper mineral. Fine grain size and smallness of quantity precluded optical and chemical identification but sufficient was available for x-ray work. The diffraction pattern proved conclusively that the green stain was paratacamite, a copper oxychloride mineral chemically but not physically identical with the common mineral atacamite. Positive identification was made only after preparation of artificial paratacamite, and records the first occurrence in Western Australia.

(h) One of a group of 44 specimens of corroded copper and aluminium wires submitted by the U.S. Navy for corrosion study was from the soil of a test area at the N.W. Cape. Small amounts and fine grain size of the samples again indicated x-ray diffraction work. It was during this study that the true identity of the copper mineral paratacamite mentioned above was discovered, when the x-ray pattern of the artificial copper oxychloride on the wires was seen to be identical with patterns of the natural mineral.

(i) A metamict mineral on thermal recrystallisation gave a pattern which did not conform with other known metamicts. However, it closely resembled tanteuxenite and the annerodite—samarskite series. No chemical work has yet been done.

(j) A sample described as britholite was received as an exchange specimen from the Canadian Geological Survey. Checking showed that the mineral in question was not britholite but an unidentified member of the same group. The x-ray powder pattern closely resembled that of a calcium phosphate and showed little similarity to that of lessingite, a mineral having an almost identical pattern to britholite; no patterns of britholite were available for comparison.

(k) An example of a rather involved and painstaking comparison to determine similarity was a series of samples received from the Criminal Investigation Bureau. Metal from a girl's shoe heels was suspected of having been scraped on to a road surface. The samples consisted of the actual shoes in question, and pebbles of blue metal picked from a road surface on to which aluminium had been scraped. X-ray patterns showed the heel material to be impure aluminium containing appreciable quantities of silicon and an aluminium-copper alloy. Patterns of metal fragments taken from the road allowed them to be divided into two groups:

(i) those with similar composition

(ii) those with noticeably different composition.

Since (ii) could be discounted at once as irrelevant, those in group (i) were given further study. These contained the same constituents as the heel metal in slightly different proportions, and the diffraction lines in the back reflection region had different degrees of sharpness from the patterns of the heel material. The latter factor is due to crystal size, and in the case of metals such as aluminium the crystal size is closely dependent on the heat treatment during the casting process. The crystal size may also be affected by subsequent cold working, and it was thought that the act of being scraped from the shoe heel may have had some effect on the metal's crystal size. Attempts were made to duplicate such abrasion of the heel metal, such as filing, and vigorous scraping of the heels against a hard rough rock similar to the road surface. In both cases, patterns of metal taken from the file and the rock evidenced no appreciable change in sharpness of back reflection lines. This demonstrated that the difference in such sharpness, i.e. in crystal size, was a valid point of difference between the metal from the shoe heels and the metal taken from the road surface. The other point of difference, i.e. the different concentration of some of the constituents such as silicon and the aluminium copper alloy, was verified spectrographically.

DIVISION VIII

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Annual Report of the Chief Inspector of Explosives for the Year 1963

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I am pleased to inform the Hon. Minister for Mines on the functioning and activities of the Explosives Branch for the year 1963.

Organization

Charged with administration of the Explosives and Dangerous Goods Act (1961) and Regulations, the Chief Inspector in professional association with the Inspector comprise the technical staff headquartered in Perth. The C-Class Reserve at Woodman's Point, S. Coogee, in which the Branch's inspectional and investigational work is largely centered, is under immediate control of a Magazine Keeper with the rank of Sub-Inspector. He has an Assistant and Staff of four watchmen who, with relief as required, alternate periods of night patrol with general duties which may include assistance in sampling and preparation of materials for inspection. The State's only other continuously manned Government Explosives Reserve is at Kalgoorlie where, however, the resident officer-in-charge is employed privately.

Accommodation

For yet another year, administrative and clerical duties were conducted from two offices, neither of which offered proper privacy nor prospect of housing additional staff as required. At the Reserve, the Magazine Keeper's 60 year old residence was deemed due for replacement and the need of modern guardhouse facilities became apparent. It was gratifying to receive approval in principle for these projects, but the office accommodation problem defied resolution with headquarters presently located in a basement not adaptable to enlargement or subdivision.

Staff

Further technical assistance, now desirable, will become essentially requisite under full impact of the new Act and Regulations. As in 1962, country inspectional activity had to be subjugated in some measure to other duties at the very time when increased explosives usage in geoseismology and ore winning demanded departmental attention, often at distant localities.

Importation

Explosives of Eastern States origin continued to reach Western Australia in approximately equal proportions by sea to Woodman's Point jetty and transcontinental railage with Kalgoorlie as terminus. A trend toward supplementing coastal stocks from this point was sustained, and expected to assum greater importance on completion of the wide-gauge line. Shipping, however, must retain its function in the supply position, especially as explosives of American manufacture will shortly be marketed here. A scheme peculiarly adaptable to such traffic and holding promise with other seaborne explosives provides the discharge as required at Derby, Point Samson or Broome on a southward voyage to Woodman's Point. Advantages of establishing dumps relatively near to heavy consuming localities without resort to long road haulage are obvious.

Ammonium nitrate, the principal component of blasting agent, also arrived by sea and rail in ratio difficult to assess because of the various importers concerned and lack of definition as to the product's intended use agriculturally or as explosive. The well-known Spencer Prill, for example, was conspicuously labelled "Ammonium Nitrate Fertilizer Grade . . ." on every drum. None came in through Woodman's Point or Esperance, notwithstanding earlier interest in the latter port. A continued adequate supply from ships at Fremantle was assisted by liberalization of permissible quantities at ordinary berths, as described later.

Types of Explosives and Blasting Agents

Except for certain geoseismic and marine explosives known as nitro-carbo-nitrates and based on ammonium nitrate, reducing agents and booster compounds, no deviation from the conventional gunpowder and nitroglycerin-glycol types occurred among the State's importations for 1963. Blasting agent composition remained unaltered chemically, an improved physical form of ammonium nitrate was introduced, but despite several inquiries, there was no recorded use of slurries or other preparations in which the usual components were replaced wholly or in part by molasses, powdered aluminium or sodium nitrate.

Authorisation of Explosives

As required by law, samples of all new explosives intended for entry to the State were submitted for authorisation. Acceptance or rejection was based on results of a comprehensive examination involving chemical analysis, stability, velocity, sensitivity, fume and firing tests, keeping qualities and safety in handling, conveyance, storage and use. By courtesy of the Explosives Department of New South Wales, the writer's colleague Mr. G. A. Greaves associated himself for some ten days in September with the explosives chemist and technical staff at Sydney, where the materials under discussion were already authorised and well known. As a result, the following explosives were added to the Authorised List in Western Australia:—

Class 3.	*Nitro-Compound.*
Division 1—	
Special Gelatine	Hi Velocity
Du Pont Gelatine	Seismograph Hi Velocity
Gelex	Gelobel
Red Arrow	Win Coal
Division 2—	
Seismex	Nitramon S
Seismex Primer	Nitramon WW
Water Work Boosters	Nitramon S Primers
H.P.D. Primers	

Use of Explosives and Blasting Agents

For reasons previously outlined and complications introduced by certain private direct importations of ammonium nitrate, the ratio of conventional explosives to blasting agent usage in various industries remained indeterminable. In total, however, available figures established the proportion at 1:1.08, or slightly greater when the weight of admixed oil was reckoned. Some changes in the pattern of usage were noted. Goldmining required 34%, coal 7.2, geoseismic work 17.3, quarrying and non-auriferous mining 7.6, Commonwealth Public Works 1.9, State Public Works 3.0, local Government works 0.5, construction 21.4 and miscellaneous purposes 8.0.

Packaging Materials

A continued trend toward replacement of wood and paper by fibreboard and plastic sheet was recorded. Few explosives and accessories appeared in their familiar trappings of even five years ago, the latest changes including fibreboard for fuse boxes and inner detonator containers. In the latter instance, however, the robust outer wooden cases have been retained. Paper remained unchallenged as an immediate cartridge wrapping except where explosive or blasting agent composition was bulk-charged into polythene for use in wet holes. Polythene bags holding 5 lb. of cartridged explosives, 10 to a case, have largely superseded the card-board-waxed paper cartons, with advantages of transparency to permit of a ready check on the contents, and ease of resealing by banding or folding the opening.

Sealed in corrosion-proofed heavy drums, most overseas ammonium nitrate was of satisfactory quality. Against this, some glaring instances of damage ascribable to packaging defects were encountered. For example, one consignment allegedly carried as deck cargo suffered severely by ingress of water to the sub-standard and apparently unprotected packages, whilst in another a physical breakdown of the prill impaired oil absorption. Excessive temperature could have been blamed, but over matters such as stowage and original packaging the Branch had virtually no authority. Inspection on arrival proved impracticable because ammonium nitrate was not necessarily handled through explosives anchorages, and neither was its intended purpose always designated. Latterly the Harbour Master and officers of the Trust at Fremantle have performed valuable service in reporting ammonium nitrate shipping movements and the condition of the containers.

Railed supplies in 50 and 80 lb. polythene heat-sealed bags proved much less prone to leakage than the former stitched closure.

The Quality of Explosives and Blasting Agents

Except for mechanical damage mentioned above, ammonium nitrate for blasting use was found by analysis to comply with chemical requirements as to permissible organic matter. Oil absorption showed variation, the prilled product being entirely satisfactory, against which oil segregation from other samples incapable of holding the optimum 5.6 to 6% was blamed for poor performance and even erratic behaviour of safety fuse in contact with the mixture. With development of improved absorption characteristics, the trouble abated later in the year. An interesting point emerging from this work was that over-avid absorption may create local high concentration to the detriment of homogeneity in the blasting agent as ordinarily prepared.

Conventional explosives, by which is meant factory-manufactured lines as distinct from blasting agent components for mixing at the point of use, proved acceptable in terms of stability, conformity with definition, detonation velocity and sensitivity. The last-named property was found well developed in American gelignite types—a desirable characteristic in ensuring propagation down the shothole. Samples of imported detonators and fuse were likewise examined and pronounced free from fault, although two makes of fuse, also of American origin, burnt at a slower rate than the 80 to 100 seconds per yard range required by the Mines Regulation Act Regulations.

Disposal of Unserviceable Materials

The usual destruction by burning of residual samples and other unwanted explosives, including some hundredweights of police exhibits, took place without incident. The only recorded dumping at sea was when H.M.A.S. Diamantina berthed at Woodman's Point Explosives Reserve jetty to receive a quantity of ordnance by rail and road from R.A.N.R. Depot at Byford.

An unusual task confronted the Branch in July when called to a North Fremantle paint factory for inspection and removal of an old 44 gallon drum of industrial nitrocellulose, believed drained of wetting medium by leakage and therefore dangerously sensitive to spark or flame. With due precautions, it was conveyed to an isolated beach at the Explosives Reserve, opened, found still moist, and samples were removed for burning which, despite the bright flash, caused only superficial destruction. The process, repeated several times after further drying intervals, proved so tedious that mass destruction under stimulus of a small gelignite charge was then attempted—with positive effect. The noise was heard half a mile away, the drum rent and not a trace of the nitrocellulose remained, although slight cratering in the sand perhaps indicated extremely rapid combustion rather than high-order explosion. However interpreted, the result emphasised the hazards associated with certain chemicals not ordinarily categorized as explosives.

Services Explosives Movements

In addition to the above-mentioned dumping operation, officers of the Branch exercised inspectional function over various ordnance movements to and from H.M.A.S. vessels at North Wharf, Fremantle.

Magazine and Store Inspections

Although no State-wide coverage was possible, many country towns and most heavily-consuming mining and industrial works received their share of attention. Recent undertakings like the Avon Valley railway diversion, bauxite mining and several newly-opened quarries all required inspectional service connected with decisions on types and positioning of magazines. Several visits were necessary in the instance of works which progressed beyond their original location. Generally, explosives in magazines or on licensed resellers' premises were in satisfactory condition. In the small quantities condemned, moisture absorption was the principal cause of spoilage.

Though not subject to the same rigorous conditions and isolation as explosives, ammonium nitrate storage assumed dimensions calling for regulation. The Branch's recommendations were well observed, particularly by large mines and similar concerns in establishing commendably high standards of storage and mixing.

Mispossession of Explosives

Children playing around earthworks near Fremantle removed detonators from an open package left overnight on a bulldozer. Action was duly taken against the driver-shotfirer and his employer. An instance of gelignite sold to a young boy by a Margaret River licensed vendor was viewed seriously and dealt with accordingly.

Criminal Misuse of Explosives

Officers of the C.I.B. and the writer investigated the wrecking by explosion of two fishing vessels at Coleman's jetty, North Fremantle, on 12th April. A 24 ft. bondwood boat was broken in two and a 52 ft. converted pearling lugger badly holed, its engine displaced and smashed and propeller shaft sheared. There being no evidence of fire or fuel-vapor explosion, the use of an explosive charge either placed against the hull or thrown from a passing craft was inferred. Skindivers searched unsuccessfully for fuse remnants, and close internal examination of both vessels when raised failed to determine the type or weight of explosives employed.

On 17th November, thieves using stolen oxy-acetylene equipment holed the safe door of a Palmyra bank for insertion of an explosive charge—which acted with devastating effect. Maybe some form of plastic explosive was forced in under pressure because the small aperture and narrow space bounded by a backing plate would barely accommodate ordinary plugs. Burnt-out fuse and scorch marks on a carpet were found, but as in the river explosion there was insufficient evidence on which to name the explosive or quantity used.

Attendance at Conferences

The Australian Dangerous Goods Transport Committee, meeting at Sydney on May 14-15, traversed a comprehensive field of hazardous goods, including radioactive substances, and recommendations were subsequently submitted to the relevant authority under auspicies of the United Nations Organisation.

In Melbourne on July 11-12 the Sub-Committee of the Australian Port Authorities' Association, comprising State harbour masters and heads of explosives departments, met in conference mainly to resolve points appertaining to importation of ammonium nitrate. After analysing the properties of this substance, its packaging, stowage and transport, delegates passed the following resolutions—

(1) The permissible tonnage of drummed ammonium nitrate for discharge from ships at non-isolated berths be increased from 75 to 150.

(2) Provided not at adjoining berths, several such shipments may be worked simultaneously.

Though subject to ratification by the Permanent Committee, these recommendations became operative in West Australia forthwith. Under former restrictions, continued adequate supplies could not have been maintained.

Outside of conference sessions, opportunity was taken whilst in the Eastern States to discuss departmental matters of explosives, blasting agents and dangerous goods. As already mentioned, Mr. G. A. Greaves later engaged in a more comprehensive mission, with advantage to the Branch generally and particularly in the fields of explosives authorisations and dangerous goods control.

Explosives and Dangerous Goods Act, 1961

Gazetted late in the year, explosives regulations should become fully operative in 1964. Contingent matters such as printing of new license forms, permits, import authorities, etc. were in progress. Preparation of regulations for Dangerous Goods control proved a more formidable task involving seemingly interminable investigation of legislation elsewhere and conferences with interested parties.

Miscellaneous Duties

An inquiry directed to the Branch on the effect of quarry blasting on masonry structures at a nearby sulphuric acid plant was answered by the State Mining Engineer after measurements with a Sprengnether vibrograph. Before acquisition of this instrument, vibration problems defied precise solution because of an indeterminate factor in the mathematical expression relating weight, distance and amplitude.

Radio frequency energy, even from low-wattage mobile transmitters, may endanger electric detonators and blasting circuits. First discussed at the Perth Explosives Conference in 1958, the subject was recently brought up to date by receipt of information and safety distance tables from the Institute of Makers of Explosives, New York. On the basis of this publication, several local problems were solved.

Application for authority to import and sell American explosives brought in its wake many considerations such as testing and inspectional requirements, siting and specifications for magaines, traction, conveyance, lighterage, shipping and even potentialities of northerly ports. Interest was also evinced in the State's explosives market by a West German concern and a Swiss manufacturer of detonating fuse. Locally, a departmental report was prepared on the practicability of a nitrogen fixation industry, with special reference to synthesis of ammonium nitrate for explosives, blasting agent and agricultural use.

Fireworks

A declining trade was evident from smaller importations and a remarkable reduction in the number of licensed vendors. Accidents were few; admittedly there could have been many unreported instances of burns needing medical attention, but a well-known oculist declared he had treated less eye injuries than during previous seasons.

Departmental vigilance over all fireworks entering the State underwent no relaxation. One manufacturer sought to circumvent the ban on plastic-coned rockets by substituting stiffened paper, which was also condemned when found unduly hard and penetrative. Japanese Silver Wheels and Triangle Wheels were rejected under Section 12 of the Regulations because components intended as fixtures were projected on ignition into erratic unpredictable flight. The tendency to shed wicks was the reason for turning down some Chinese rockets.

A Sydney distributor sent samples of posters and safety pointers ("Ten Golden Rules") for the handling and lighting of fireworks. All essential precautions were outlined in a simple easily-read style. Copies were to be supplied to purchasers of at least one English manufacturer's products next year.

Another English company forwarded to the Branch a box of firework lighters, hitherto unknown here. Outwardly resembling sparklers, these articles on ignition were found to smoulder flamelessly for 45 minutes at a temperature sufficient to light any wick or touch-paper. Their adoption should further enhance the safety factor by encouraging the lighting of all fireworks at arm's length.

Displays

Products of two local licensed firework manufacturers were used in several exhibitions, well-staged and devoid of mishap.

Amateur Rocketry

Clandestine pursuit of this hobby undoubtedly occurred, but one instance only came to notice. A Leederville technical school lad frankly put his case before the Branch, claiming he had designed and made a rocket under his science teacher's supervision. Official permission, however, was required for purchase of chemicals to energise the motor. With certain reservations and safety recommendations he was allowed to go ahead. We in W.A. do not align with the suppressive attitude detectable in some States, believing that whilst the curious tinkerer should receive short shrift, an outright ban on properly organised pyrotechnical experimentation could be harsh and retrogressive.

Illicit Firework Manufacture

In a different category from the above is the back-yard making by juveniles of gumnut bombs or other explosive articles using metal pipe to enclose a composition which, often containing prohibited admixtures, may be dangerous even if unconfined. Apprehension that the generally milder type of fireworks now available might give incentive to unauthorised manufacture was not borne out by reported mishaps therewith.

Conclusion

To the staff both at Head Office and the Explosives Reserve gratitude is expressed for diligent discharge of duties which under present legislation and developments as described have become increasingly exacting. My superiors in the Department, officers of lesser rank and hosts of others whether governmentally or privately occupied showed co-operative understanding with whatever phase of the Branch's activities they may have been concerned.

F. F. ALLSOP,
Chief Inspector of Explosives.

DIVISION IX

Report of Chairman, Miners' Phthisis Board and Superintendent Mine Workers' Relief Act, 1963

Under Secretary for Mines:

1. I submit for the information of the Honourable Minister for Mines, my report on this Branch of the Mines Department for the year 1963.

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

3. *Mine Workers' Relief Act.*

3.1 *Total Examinations.*—The examinations under the Mine Workers' Relief Act during the year totalled 5,498 as compared with 5,760 for the previous year, a decrease of 262. The results of the examinations are as follows:—

Normal	4,795
Silicosis early previously normal	188
Silicosis early previously silicosis early	451
Silicosis advanced previously normal	Nil.
Silicosis advanced previously silicosis early	22
Silicosis advanced previously silicosis advanced	Nil.
Silicosis plus tuberculosis previously normal	7
Silicosis plus tuberculosis previously silicosis early	6
Silicosis plus tuberculosis previously silicosis advanced	Nil.
Tuberculosis previously normal	3
Asbestosis early previously normal	10
Asbestosis early previously asbestosis early or silicosis early	11
Asbestosis advanced previously normal	Nil.
Asbestosis advanced previously asbestosis early or silicosis early	4
Asbestosis advanced previously asbestosis advanced	Nil.
Asbestosis plus tuberculosis previously normal	1
Asbestosis plus tuberculosis previously asbestosis early	Nil.
Asbestosis plus tuberculosis previously asbestosis advanced	Nil.
Total	5,498

These 1963 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.

3.2 *Analyses of Examinations.*—In explanation of the examination figures, I desire to make the following comments:—

3.2.1 *Normal, etc.*—These numbered 4,795 or 87.21% of the men examined and includes men having first class lives or suffering from fibrosis only. The figures for the previous years being 5,183 or 89.98%.

3.2.2 *Early Silicosis.*—These numbered 639 of which 188 were new cases and 451 had been previously reported, the figures for 1962 being 50 and 499, respectively. Early silicotics represent 11.62% of the men examined, the percentage for the previous year being 9.53%.

3.2.3 *Advanced Silicosis.*—There were 22 cases reported all of which advanced from early silicosis during the year. Advanced silicotics represent 0.40% of the men examined, the percentage for the previous year being 0.19%.

3.2.4 *Silicosis Plus Tuberculosis.*—Thirteen cases were reported compared with six in 1962.

3.2.5 *Tuberculosis Only.*—Three cases were reported compared with one in 1962.

3.2.6. *Asbestosis.*—Four cases of advanced asbestosis, 21 cases of early asbestosis and one case of asbestosis plus tuberculosis were reported. Of the early cases ten were new and eleven had been previously reported. Cases of asbestosis represented 0.47% of the total examinations. The percentage for 1962 was 0.18%.

4. *Mines Regulation Act.*

4.1. *Total Examinations.*—Examinations under the Mines Regulation Act totalled 2,006. These were in addition to the 5,498 examinations under the Mine Workers' Relief Act. There was an increase of 194 examinations under this Act in 1963 as compared with those in 1962. Of the total of 2,006 men examined 1,649 were new applicants and 357 were re-examinees.

4.2 *Analyses of Examinations.*—Particulars of the examinations are as follows:—

4.2.1. *New Applicants.*

Normal	1,633
Silicosis early	3
Query tuberculosis	3
Tuberculosis	1
Other conditions	9
Total	1,649

4.2.2. *Re-Examinees.*

Normal	316
Increased fibrosis	20
Early silicosis	14
Query tuberculosis	2
Tuberculosis	3
Silicosis early plus query tuberculosis	1
Other conditions	1
Total	357

These men had been previously examined and some were in the industry prior to this examination.

4.2.3. *Health Certificates Issued to New Applicants and Re-Examinees.*—The following health certificates were issued under the Mines Regulation Act:—

Initial Certificates (Form 2)	1,948
Temporary Rejection Certificates (Form 3)	9
Rejection Certificates (Form 4)	14
Re-admission Certificates (Form 5)	9
Special Certificates (Form 9)	12
No certificate	14
Total	2,006

The percentage of men of normal health (Initial Certificates) to the number examined was 97.11% compared with 95.20% in 1962.

5. *Miners' Phthisis Act.*—The amount of compensation paid during the year was £9,597 1s. 8d. compared with £10,696 11s. 8d. for the previous year.

The number of beneficiaries under the Act on the 31st December, 1963, was 85, being 7 ex-miners and 78 widows.

6. *Administrative.*—During the year the regulations under the Mine Workers' Relief Act were consolidated and it is expected that these will be printed and available in one volume with the latest consolidation of the Act in 1964.

W. Y. R. GANNON,
Superintendent Mine Workers' Relief Act
and Chairman Miners' Phthisis Board.

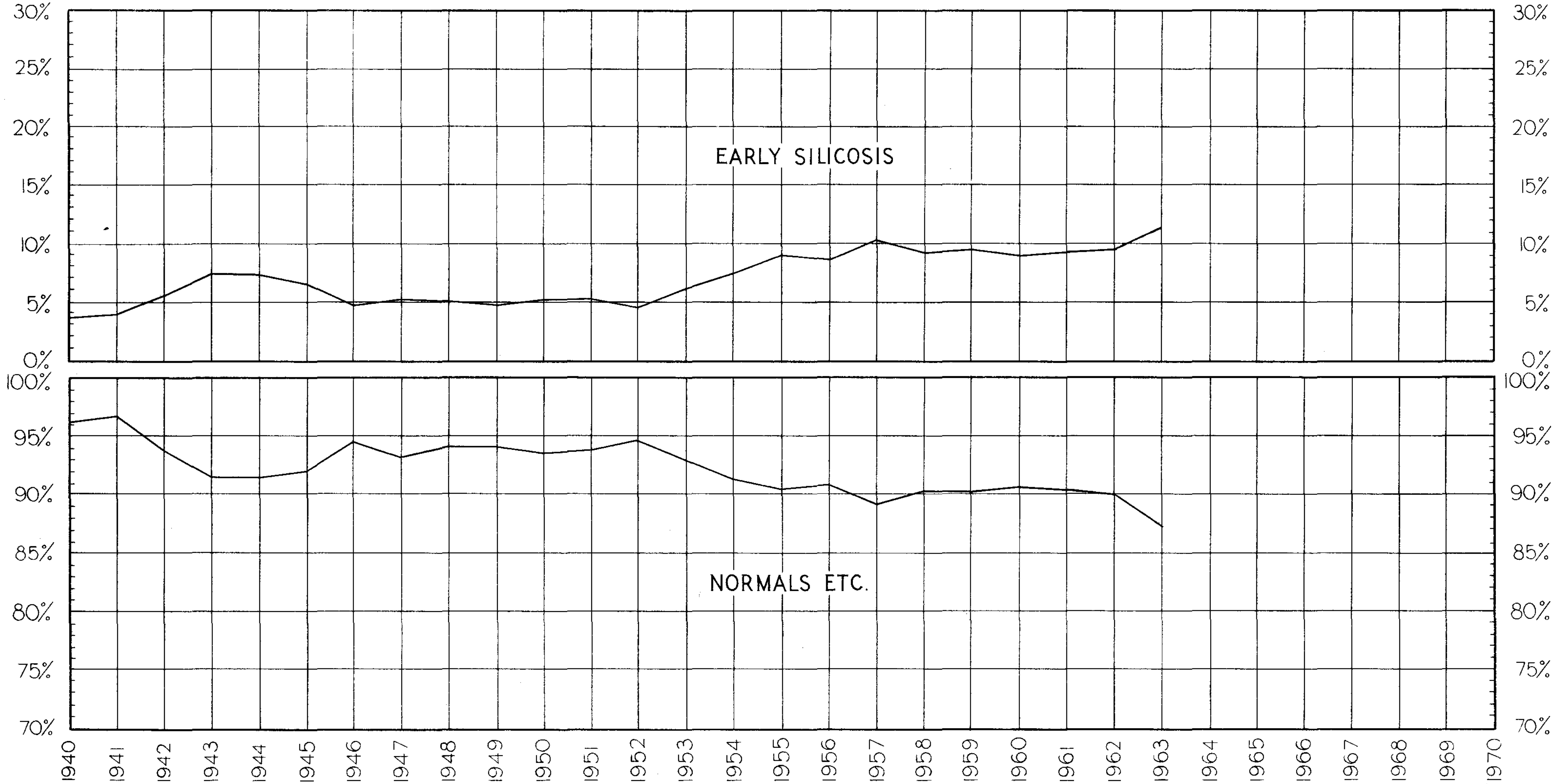
Table Showing Results of Periodical Examination of Mine Workers from Inception of Examinations (1925).

Year	Normal		Silicosis Early				Silicosis Advanced					Silicosis plus Tuberculosis					Tuberculosis Only		Asbestosis									
	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	Segregation of asbestosis diagnoses commenced in 1959									5,630
1955	4,559	90·40	63	386	449	8·90	....	9	22	31	·62	1	1	1	3	·06	1	·02	....	....	....	....	....	....	....	....	....	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	5,753
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

PERIODICAL EXAMINATION OF MINE WORKERS

GRAPH Nº 1

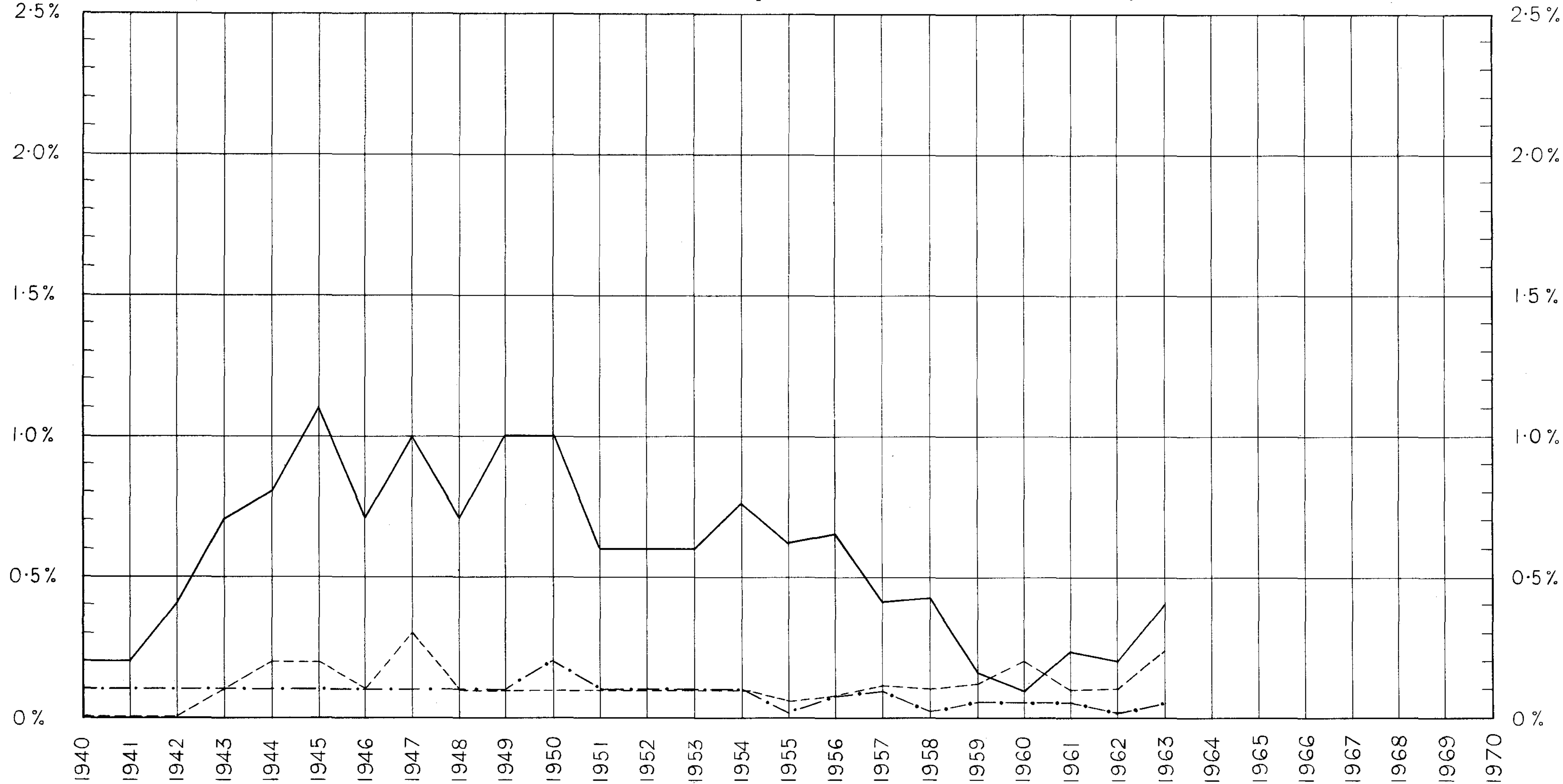
Showing Percentages of Normals and Early Silicotics from 1940 onwards



PERIODICAL EXAMINATION OF MINE WORKERS

GRAPH No. 2

Showing Percentages of Silicosis Advanced, Silicosis plus Tuberculosis and Tuberculosis only, from 1940 onwards



Silicosis Advanced ———— Silicosis Plus Tuberculosis – – – – – – Tuberculosis Only —·—·—·—

DIVISION X

Report of the Chief Draftsman for the Year 1963

Under Secretary for Mines:

I have the honour to submit for the information of the Hon. Minister for Mines, my report on the operations of the Survey and Mapping Branch for the year ended 31st December, 1963.

Staff.

The staff of the Branch totals 41. Increase of work in the various sections was maintained during the year and the demand for added information and maps of various kinds continued.

The increased scope and spread of mineral investigations has created new problems in connection with land tenure and the effects on other Departments' activities, necessitating continuous and close liaison with these various Departments and consideration of their functions.

Every effort was made during the year to have as many surveys as possible carried out and this policy will be pursued in the coming year.

The location and definition of large reserve areas in most difficult country has become necessary. Consequent on the Hamersley Iron Ore agreement a definition of the common boundaries between reserves with occupation to two different companies was carried out using a helicopter and air-photo fixing to the mutual satisfaction of the two companies and myself.

Thanks are due to the staff for their co-operation in coping with the increasing volume and complexity of the work during the year.

Reports in summarised form of the sections of the Branch are appended hereto.

L. A. JONES,
Chief Draftsman.

Surveys.

Contract surveys to the value of £7,941 11s. 6d. were carried out during 1963 by five surveyors at the following centres:—

South West Mineral Field:
- Wanneroo.
- Cliff Head.
- Arrino.
- Dooka.
- Lake King.
- Koolanooka.
- Yoganup.
- Marchagee.
- Donnybrook.
- Capel.

Greenbushes Mineral Field:
- Greenbushes.

Ashburton Goldfield:
- Learmonth (North West Cape).

Dundas Goldfield:
- Norseman.

Coolgardie Goldfield:
- Coolgardie.
- Paris.
- Widgiemooltha.
- Spargoville.

East Coolgardie Goldfield:
- Kalgoorlie.
- Boulder.
- Binduli.
- Wombola.

Pilbara Goldfield:
- Moolyella.

Yilgarn Goldfield:
- Lake Cronin.
- Dulcie.
- Parkers Range.
- Nevoria.
- Marvel Loch.
- Edwards Find.
- Southern Cross.
- Hopes Hill.
- Westonia.
- Bullfinch.

Yalgoo Goldfield:
- Dalgaranga.
- Kylie.
- Warda Warda.
- Mt. Magnet.
- Boogardie.
- Lennonville.
- Warriedar.
- Fields Find.
- Gnows Nest.

Broad Arrow Goldfield:
- Grants Patch.
- Christmas Reef.
- Ora Banda.

In addition, surveys were commenced in the Kimberley Goldfield at Halls Creek, Mt. Angela and Mt. Dockrell. Results of these surveys have not yet been lodged.

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.

Surveyors in the field were kept supplied with necessary information relating to survey details as requested from time to time.

Mapping.

(1) One hundred and fifty-two technical plans were prepared for Geological Surveys together with 4,906 prints and duplicates, from various originals.

Balfour Downs and Boorabbin 1:250,000 geological maps were published.

Dampier, Port Hedland and Mt. Bruce 1:250,000 maps were commenced with eight of the 1:50,000 series, in the vicinity of Northampton.

Hamersley Range Iron Ore Province map was produced.

(2) Miscellaneous reproductions for Chemical Laboratories, Explosives and Inspection of Machinery Branches.

Certificates and time-tables, etc., for School of Mines, Kalgoorlie.

(3) Prints and copy-rapid orders fulfilled during the year amounted to 13,339, representing an increase over the previous year of 69%.

The main mapping was as follows:—

(a) 1:50,000 Series published: Tambourah, Nullagine and Barton.

(b) Completed and awaiting publication: Joffre, Mulga Downs, Woodstock and Mungaroona Range. Fourteen others are in progress.

(c) The programme of re-drawing the 20 chains lithographic series was continued.

(d) Seven new Standard plans were compiled and surveys from field notes were plotted on the maps in the Standard system.

Public Plans.

Number of Applications dealt with	1,085
Number of Public Plans in use	757
Number of existing tenements maintained on Public Plans	4,474
Number of Maps, Plans, Sketches, Underground Plans supplied to the Public, Outstations and other Departments	1,103
Number of Temporary Reserves applied for	94
Number of Temporary Reserves in force	177
Number of Petroleum Tenements in force	96

MINING STATISTICS
to 31st December, 1963

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MINERALS OTHER THAN GOLD

TABLE 1.

PRODUCTION OF GOLD AND SILVER FROM ALL SOURCES, SHOWING IN FINE OUNCES THE OUTPUT AS REPORTED TO THE MINES DEPARTMENT DURING 1963, 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 Silver Lead Ore. ‡ Denotes mainly derived from Copper Ore. § Concentrates. || Tantalum.

Kimberley Goldfield.

Mining Centre	Number of Lease	Registered Name of Company or Lease	Total for 1963					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.
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	....	....	12·000	21·64	....	....	....	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. Dockerell	....	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	97	Ruby Queen	....	....	....	4·49	....	....	....	3,069·25	1,731·05	2·14
		Voided leases	....	....	....	....	....	....	16·05	12,902·20	9,619·82	....
		Sundry claims	....	....	....	....	....	12·71	....	281·25	183·30	....
From District generally :—												
		Sundry claims	....	....	....	....	....	....	....	....	....	†20·98
		Reported by Banks and Gold Dealers	52·20	81·51	....	....	....	8,920·90	1,975·55	·75	8·15	....
		Total	**52·20**	**81·51**	**120·00**	**26·13**	....	**9,079·68**	**3,016·35**	**22,871·90**	**17,266·45**	**128·76**

West Kimberley Goldfield.

Mining Centre	Number of Lease	Registered Name of Company or Lease	Alluvial (1963)	Dollied and Specimens (1963)	Ore treated (1963)	Gold therefrom (1963)	Silver (1963)	Alluvial (Total)	Dollied and Specimens (Total)	Ore treated (Total)	Gold therefrom (Total)	Silver (Total)
Napier Range	M.C. 29	Devonian Silver Lead Mine	....	....	....	....	....	....	....	....	....	13,575·29
From District generally :—												
		Sundry claims	....	....	....	....	....	1·30	24·68	1·00	2·49	....
		Total	....	....	....	....	....	**1·30**	**24·68**	**1·00**	**2·49**	**13,575·29**

Pilbara Goldfield.

MARBLE BAR DISTRICT.

Bamboo Creek	G.M.L. 1120	Bamboo Queen	....	....	....	....	....	....	....	88·50	30·99	·34
	G.M.L. 1107	Bulletin	....	....	....	....	....	....	....	995·25	446·03	2·02
	G.M.L. 1118	Kitchener	....	....	30·00	246·53	....	....	....	291·00	307·97	3·53
	G.M.L. 1203	Mt. Prophecy	....	....	91·00	28·95	....	....	....	91·00	28·95	....
	(1096), (1097), 1095	Mt. Prophecy Leases	....	....	....	....	....	....	24·50	3,053·00	1,096·72	49·63
	817	Prince Charlie	....	....	521·00	239·01	12·13	....	3·68	9,375·75	6,370·48	281·29
	924	True Blue	....	....	313·50	....	....	·62	....	4,671·25	114·64	·22
	1072	Princess May	....	....	....	....	....	....	....	92·50	24·27	....
		Voided leases	....	....	....	....	....	13·54	568·41	49,263·85	55,709·29	8·97
		Sundry claims	....	....	....	....	....	8·97	307·83	5,208·85	3,034·45	7·21
Boodalyerrie	....	Voided leases	....	....	....	....	....	....	292·07	120·25	587·86	....
		Sundry claims	....	....	....	....	....	....	7·16	....	....	....
Braeside	....	Sundry claims and producers	....	....	....	....	....	....	....	....	....	†21,960·80
		Braeside Lead Mines	....	....	....	....	....	....	....	....	....	†3,892·95
Lalla Rookh	....	Voided leases	....	....	....	....	....	....	4·78	3,612·00	4,696·33	574·01
		Sundry claims	....	....	182·75	183·70	....	....	....	8,125·75	7,858·79	....
Marble Bar	G.M.L. 930 (956)	Alexander Leases	....	....	....	....	....	....	....	354·50	120·94	·81
	930	Alexander	....	....	....	....	....	....	....	640·00	114·59	....
	1094	Blue Bar	....	....	....	....	....	....	....	1,187·50	167·19	·48
	927, etc.	Halley's Comet	....	....	....	....	....	....	....	6,360·00	6,390·33	680·36
	1121	Little Portree	....	....	....	....	....	....	....	103·00	66·88	6·93
		Voided leases	....	....	....	....	....	45·98	199·09	165,957·49	151,729·10	595·61
		Sundry claims	....	....	15·00	18·79	....	67·08	255·30	21,503·54	12,865·71	9·43
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	....	....	....	....	....	2·84	579·91	179·75	121·72	....
Pilgangoora	(1205)	Jeanette	....	....	24·00	3·97	....	....	....	24·00	3·97	....
	M.C. 291	Northern Territory Prospecting and Development Co. Ltd.	....	....	....	....	....	....	2·12	....	39·54	....
		Voided leases	....	....	....	....	....	16·65	....	2,255·00	403·60	....
		Sundry claims	....	....	58·00	88·14	....	161·08	45·64	541·60	238·29	....
Sharks	G.M.L. 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 1963					Total Production				
			Alluvial	Dollied and Specimens	Ore treated	Gold therefrom	Silver	Alluvial	Dollied and Specimens	Ore treated	Gold therefrom	Silver
			Fine ozs.	Fine ozs.	Tons (2,240 lb.)	Fine ozs.	Fine ozs.	Fine ozs.	Fine ozs.	Tons (2,240 lb.)	Fine ozs.	Fine ozs.
PILBARA GOLDFIELD—continued.												
MARBLE BAR DISTRICT—*continued.*												
Warrawoona	1193	Trump	....	....	....	....	....	....	....	228·50	16·70	·96
		Voided leases	....	....	....	....	....	....	16·99	17,749·30	19,645·44	23·70
		Sundry claims	....	....	....	....	....	70·98	623·67	6,632·79	4,247·38	·08
Western Shaw	....	Voided leases	....	....	....	....	....	....	....	1,222·50	957·80	....
		Sundry claims	....	....	....	....	....	22·34	67·47	71·50	81·49	....
Wodgina	....	Sundry claims	....	....	....	....	....	....	43·37	·50	....	3·25
Wyman's Well	1084	New Copenhagen	....	....	....	....	....	....	....	770·55	165·52	4·34
		Voided leases	....	....	....	....	....	....	42·86	2,977·29	1,258·44	....
		Sundry claims	....	....	....	....	....	4·47	51·52	2,732·71	1,324·64	1·47
Yandicoogina	....	Voided leases	....	....	....	....	....	....	140·76	3,159·20	6,218·83	....
		Sundry claims	....	....	....	....	....	4·32	239·89	622·25	682·47	45·96
	From District generally :—											
	Sundry Parcels treated at :											
		H. B. & C. L. Dorrington (L.T.T. 1451H)	....	....	....	....	....	....	....	94·00	3·47	·42
		H. N. Flegg (L.T.T. 1439H)	....	....	....	....	....	....	....	....	1·04	....
		State Battery, Bamboo Creek	....	....	....	*219·76	34·31	....	....	40·00	*12,149·23	370·64
		State Battery, Marble Bar	....	....	....	*458·46	32·14	....	....	12·00	*12,541·53	95·50
		Various Works	....	....	....	....	....	....	....	286·95	* 1,919·97	5·54
	Reported by Banks and Gold Dealers		48·84	·20	....	....	·37	14,558·20	457·21	....	15·41	2,224·90
		Total	**48·84**	**·20**	**1,235·25**	**1,487·31**	**78·95**	**15,314·86**	**4,569·14**	**341,601·72**	**330,545·29**	**32,902·64**
NULLAGINE DISTRICT.												
Eastern Creek	....	Voided leases	....	....	....	....	....	8·96	8·19	5,594·00	9,854·21	14·76
		Sundry claims	....	....	33·00	6·77	....	....	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	....	....	380·00	108·71	·36	1·22	....	9,566·75	4,655·81	38·24
	231L, etc.	North-West Mining N.L.	....	....	....	....	....	....	....	9,782·07	6,174·22	....
	231L, etc.	Prior to Transfer to Present Holders	....	....	....	....	....	....	....	53,391·41	32,009·01	10·99
		Voided leases	....	....	....	....	....	....	1·02	18,813·15	11,745·73	8·37

		Sundry claims	....	....	253·00	61·03	....	....	18·69	6,750·60	2,643·14	2·38
Mosquito Creek	331L	Ard Patrick	....	....	....	....	....	10·80	....	78·00	19·75	....
		Voided leases	....	....	....	....	....	1·07	30·12	8,392·30	12,839·13	....
		Sundry claims	....	....	....	....	....	....	181·64	3,707·44	3,789·21	....
Nullagine	292L	Alice	....	....	....	....	....	3·85	1,159·85	138·85	331·29	63·45
		Voided leases	....	....	....	....	....	....	599·59	9,393·75	13,457·00	41·07
		Sundry claims	....	....	11·00	10·83	·88	321·36	689·71	6,640·45	10,563·70	18·45
Spinaway Well	G.M.L. 314L	Copper Hills Copper Mine	....	....	....	....	....	....	....	....	‡15·44	‡483·78
Twenty Mile Sandy	M.C. 112L	J. C. and G. M. Baker	....	....	....	....	....	....	....	....	·93	‡51·20
		Voided leases	....	....	....	....	....	....	16·97	7,243·70	9,007·72	320·50
		Sundry claims	....	....	....	....	....	33·10	30·50	7,793·85	6,283·29	2·76
		From District generally :—										
		Sundry Parcels treated at :										
		Paddy Luba (L.T.T. 2L/1962)	....	....	21·25	1·75	....	....	....	21·25	1·75	....
		Barton Battery	....	....	....	....	....	....	....	....	*45·19	....
		McKinnon's Sluicing Plant (D.C.s 10L, 14L, 15L)	....	....	....	....	....	3·89	2·23	....	7·20	....
		Various Works	....	....	....	....	....	....	....	124·50	8,110·35	1·37
		Reported by Banks and Gold Dealers	38·91	....	....	....	....	10,096·27	147·52	....	48·03	5·95
		Total	**38·91**	....	**698·25**	**189·09**	**1·24**	**10,480·52**	**2,907·05**	**149,804·42**	**135,429·02**	**1,080·29**

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	....

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 1963					Total Production				
			Alluvial	Dollied and Specimens	Ore treated	Gold therefrom	Silver	Alluvial	Dollied and Specimens	Ore treated	Gold therefrom	Silver
			Fine ozs.	Fine ozs.	Tons (2,240 lb.)	Fine ozs.	Fine ozs.	Fine ozs.	Fine ozs.	Tons (2,240 lb.)	Fine ozs.	Fine ozs.
		WEST PILBARA GOLDFIELD—continued.										
Weerianna	....	Voided leases	....	....	....	....	....	....	....	3,200·15	3,214·45	....
		Sundry claims	....	....	....	....	....	....	....	336·00	135·26	1·29
Whim Creek	....	Voided leases	....	....	....	....	....	....	....	....	....	883·80
	From Goldfield generally :—											
	Sundry Parcels treated at :											
		Various Works	....	....	....	....	....	....	....	....	*102·39	4·90
		Sundry claims and leases	....	....	....	....	....	....	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	Alluvial (1963)	Dollied and Specimens (1963)	Ore treated (1963)	Gold therefrom (1963)	Silver (1963)	Alluvial (Total)	Dollied and Specimens (Total)	Ore treated (Total)	Gold therefrom (Total)	Silver (Total)
Belvedere	....	Voided leases	....	....	....	....	....	....	9·88	1,560·00	435·86	176·48
Dead Finish	....	Voided leases	....	....	....	....	....	....	....	1,699·00	874·60	·03
		Sundry claims	....	....	....	....	....	....	11·89	104·25	245·08	....
Linden Station	....	Sundry claims	....	....	....	....	....	....	....	128·35	203·51	....
Melrose	....	Voided leases	....	....	....	....	....	....	....	2,704·00	840·26	213·11
		Sundry claims	....	....	....	....	....	12·41	21·88	562·00	262·78	6·40
Mt. Edith....	....	Sundry claims	....	....	....	....	....	....	....	5·00	3·97	....
Mt. Mortimer	....	Sundry claims	....	....	....	....	....	364·63	315·64	44·50	40·25	74·47
Uaroo	....	Voided leases	....	....	....	....	....	....	....	....	....	7,713·22
	From Goldfield generally :—											
		Sundry claims (Silver Lead)	....	....	....	....	....	....	....	....	....	33,787·67
		Reported by Banks and Gold Dealers	....	....	....	....	....	8,890·33	123·17	....	7·12	....
		Total	....	....	....	....	....	**9,267·37**	**482·46**	**6,807·10**	**2,913·43**	**41,971·38**

Gascoyne Goldfield.

Mining Centre	Number of Lease	Registered Name of Company or Lease	Alluvial (1963)	Dollied and Specimens (1963)	Ore treated (1963)	Gold therefrom (1963)	Silver (1963)	Alluvial (Total)	Dollied and Specimens (Total)	Ore treated (Total)	Gold therefrom (Total)	Silver (Total)
Bangemall	....	Voided leases	....	....	....	....	....	....	6·22	350·70	313·82	....
		Sundry claims	....	....	....	....	....	88·97	33·55	36·30	203·47	....
Carnarvon	G.M.L. 46	Star Mangaroon	....	1·77	124·25	239·71	9·68	....	2·54	305·75	717·52	19·30
	M.C.	Allen MacDonald	....	....	....	....	....	....	49·09	....	....	26·92
		Sundry claims	....	....	....	....	....	....	....	97·00	376·12	....

	From Goldfield generally :—											
		Reported by Banks and Gold Dealers	....	....	....	....	....	609·16	28·97	....	2·56	....
		Total	....	**1·77**	**124·25**	**239·71**	**9·68**	**698·13**	**120·37**	**789·75**	**1,613·49**	**46·22**

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, etc.	Anglo-Westralian Mining Co. Pty. Ltd.	....	....	....	....	....	....	....	135,872·00	22,870·80	1,407·05
	568P	Horseshoe Lights (Prior to Transfer)	....	....	....	....	....	....	....	3,914·00	894·44	....
		Voided leases	....	....	....	....	....	15·57	1,975·37	5,654·38	2,818·56	2·00
		Sundry claims	....	....	....	16·89	1·09	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	602P	Duffer	....	....	....	....	....	....	....	9·50	15·32	....
		Voided leases	....	....	....	....	....	....	....	389·50	320·96	....
		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	512P	Atlantic	....	....	....	....	....	1·69	2·87	5,399·75	628·42	1·52
	511P	Commercial	....	....	....	....	....	....	....	4,281·25	634·40	1·70
	584P	Dazzle Star	....	....	....	....	....	....	....	329·00	99·97	·50
	567P	Miner Bird	....	....	....	....	....	....	....	2,213·00	967·52	1·68
	553P	Morning Star	....	....	420·00	38·71	1·61	....	4·43	4,925·75	636·26	8·40
	492P	North Star	....	....	....	....	....	23·20	69·63	13,371·50	2,091·89	....
		Voided leases	....	....	....	....	....	7·39	1,006·68	532,109·03	248,951·40	2,288·81
		Sundry claims	....	....	397·00	31·86	·86	61·51	306·63	35,365·35	9,030·99	2·76
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 :—											
	Australian Machinery & Investment Co. Plant		....	....	....	....	....	....	....	....	*1,686·20	....
	State Battery, Peak Hill		....	....	....	....	....	....	3·05	15·00	*7,171·41	....
	Various works		....	....	....	....	....	....	....	1,332·00	*5,723·81	23·12
	Reported by Banks and Gold Dealers		....	....	....	....	....	2,858·58	444·91	....	15·88	·14
		Total	....	....	**817·00**	**87·46**	**3·56**	**3,387·79**	**5,300·88**	**781,766·73**	**322,689·99**	**3,789·83**

Table I.—*Production of Gold and Silver from all sources, etc.*—continued.

East Murchison Goldfield.

LAWLERS DISTRICT.

Mining Centre	Number of Lease	Registered Name of Company or Lease	Total for 1963: Alluvial (Fine ozs.)	Total for 1963: Dollied and Specimens (Fine ozs.)	Total for 1963: Ore treated (Tons (2,240 lb.))	Total for 1963: Gold therefrom (Fine ozs.)	Total for 1963: Silver (Fine ozs.)	Total Production: Alluvial (Fine ozs.)	Total Production: Dollied and Specimens (Fine ozs.)	Total Production: Ore treated (Tons (2,240 lb.))	Total Production: Gold therefrom (Fine ozs.)	Total Production: Silver (Fine ozs.)
Kathleen Valley	....	Voided leases	....	....	....	....	....	....	144·85	80,963·66	49,054·32	1·57
		Sundry claims	....	....	....	....	....	14·37	526·03	5,836·75	2,662·74	893·45
Lawlers	G.M.L. 1363, etc.	Kim Prospecting & Development Syndicate	....	....	....	....	....	....	....	290·00	25·64	....
	1356, etc.	Waroonga	....	....	....	....	....	....	....	....	99·40	·50
		Voided leases	....	....	....	....	....	25·51	692·45	1,622,917·40	575,150·65	14,803·08
		Sundry claims	....	....	....	....	....	401·71	451·61	17,707·48	9,779·27	274·09
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	1367	Tahmoo	....	....	....	....	....	....	....	690·00	274·60	·28
	1372	Vicky Sue	....	....	63·50	7·67	·50	....	....	63·50	7·67	·50
		Sundry claims	....	....	209·50	134·78	6·67	143·23	....	417·75	231·72	10·53
		From District generally :— Sundry Parcels treated at :—										
		State Battery, Sir Samuel	....	....	....	....	....	....	....	53·50	*2,356·81	....
		Vanguard Cyanide Plant	....	....	....	....	....	....	....	4·00	*1,014·04	3·18
		Western Machinery Co. Pty. Ltd.	....	....	....	....	....	....	....	5·00	*4,291·25	29·00
		Prior to transfer to present holders	....	....	....	....	....	....	....	....	*1,371·33	15·64
		Various Works	....	....	....	....	....	2·12	2·35	1,711·53	30,788·76	936·21
		Reported by Banks and Gold Dealers	....	....	....	....	....	6,458·80	101·91	·05	10·00	....
		Total	....	....	**273·00**	**142·45**	**7·17**	**7,103·38**	**2,343·19**	**2,013,929·17**	**823,532·82**	**27,202·85**

WILUNA DISTRICT.

Mining Centre	Number of Lease	Registered Name of Company or Lease	Total for 1963: Alluvial (Fine ozs.)	Total for 1963: Dollied and Specimens (Fine ozs.)	Total for 1963: Ore treated (Tons (2,240 lb.))	Total for 1963: Gold therefrom (Fine ozs.)	Total for 1963: Silver (Fine ozs.)	Total Production: Alluvial (Fine ozs.)	Total Production: Dollied and Specimens (Fine ozs.)	Total Production: Ore treated (Tons (2,240 lb.))	Total Production: Gold therefrom (Fine ozs.)	Total Production: Silver (Fine ozs.)
Coles	....	Voided leases	....	....	....	....	....	....	....	2,765·50	1,240·40	....
		Sundry claims	....	....	35·00	4·68	·23	....	21·03	3,899·50	1,515·22	·55
Corboys	....	Voided leases	....	....	....	....	....	5·24	1·25	14,946·29	11,036·71	5·00
		Sundry claims	....	....	....	....	....	21·58	....	9,082·35	5,210·79	....
Gum Creek	....	Voided leases	....	....	....	....	....	20·75	....	1,380·00	595·73	....
		Sundry claims	....	....	....	....	....	....	1·36	407·25	131·08	....
Mt. Eureka	....	Voided leases	....	....	....	....	....	....	....	142·25	96·36	....
		Sundry claims	....	....	....	....	....	....	....	783·75	548·56	....
Mt. Keith	....	Voided leases	....	....	....	....	....	....	44·54	20,259·50	13,551·08	....
		Sundry claims	....	....	....	....	....	4·81	227·29	3,868·50	2,485·06	·99

New England	....	Voided leases	....	....	....	....	....	5·74	95·70	5,364·25	3,490·87	....
		Sundry claims	....	....	....	....	....	9·31	5·78	4,534·75	3,111·97	....
Wiluna	....	Voided leases	....	....	....	....	....	....	574·76	8,777,986·65	1,789,127·12	10,049·13
		Sundry claims	....	....	....	....	....	105·39	225·82	27,442·65	10,897·38	·33
	From District generally :—											
	Sundry Parcels treated at :—											
	T. J. Jones (L.T.T. Plant 1446H)	....	....	....	....	*59·20	6·61	....	....	....	*59·20	6·61
	T. J. Jones (L.T.T. 1s/61)	....	....	....	....	....	....	....	....	....	*5·43	·18
	State Battery, Wiluna	....	....	....	....	....	....	....	....	637·00	*23,679·00	219·70
	Various Works	....	....	....	....	....	....	....	....	139·00	5,322·12	12·72
	Reported by Banks and Gold Dealers	....	....	....	....	....	....	63·66	56·58	....	158·54	12·02
		Total	....	....	**35·00**	**63·88**	**6·84**	**236·48**	**1,254·11**	**8,873,639·19**	**1,872,262·62**	**10,307·23**

BLACK RANGE DISTRICT.

Barambie	G.M.L. (1116B)	Dingo	....	....	2·75	18·54	·20	....	....	3·75	220·47	·20
	1117B	Sheelite Leases	....	....	34·75	45·17	2·45	....	....	901·50	576·90	11·02
		Voided leases	....	....	....	....	....	....	22·49	18,554·67	17,363·81	125·60
		Sundry claims	....	....	....	....	....	5·07	170·20	978·55	1,062·22	216·73
Bellchambers	....	Voided leases	....	....	....	....	....	....	111·80	4,349·27	3,130·56	....
		Sundry claims	....	....	....	....	....	....	....	1,182·80	557·95	....
Birrigrin	....	Voided leases	....	....	....	....	....	....	820·68	12,042·93	15,086·09	....
		Sundry claims	....	....	....	....	....	....	179·92	2,487·55	1,238·22	....
Currans	....	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	....
Montague	....	Voided leases	....	....	....	....	....	....	100·17	79,550·60	23,444·82	....
		Sundry claims	....	....	....	....	....	....	71·09	5,041·35	3,171·19	....
Nungarra	(1123B)	Winora	....	....	200·00	7·47	·25	....	....	200·00	7·47	·25
		Voided leases	....	....	....	....	....	25·94	952·34	9,509·00	3,655·49	....
		Sundry claims	....	....	....	....	....	50·27	1,458·98	7,682·40	2,960·27	....
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	15,998·95	6,928·81	....
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	....

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 1963					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.												
BLACK RANGE DISTRICT—continued.												
	From District generally :—											
	Sundry Parcels treated at :—											
	State Battery, Sandstone		....	....	....	....	....	....	....	290·50	*23,575·34	61·02
	State Battery, Youanmi		....	....	....	....	....	....	....	40·00	*5,504·08	....
	Various Works		....	....	....	....	....	....	....	104·50	11,496·73	....
	Reported by Banks and Gold Dealers		....	....	....	....	....	1,494·98	54·36	....	20·38	·15
		Total	....	....	**237·50**	**71·18**	**2·90**	**1,670·54**	**18,609·97**	**1,731,287·97**	**955,150·15**	**22,724·16**

Murchison Goldfield.

CUE DISTRICT.

Mining Centre	Number of Lease	Registered Name of Company or Lease	Alluvial (1963)	Dollied and Specimens (1963)	Ore treated (1963)	Gold therefrom (1963)	Silver (1963)	Alluvial (Total)	Dollied and Specimens (Total)	Ore treated (Total)	Gold therefrom (Total)	Silver (Total)
Big Bell	....	Voided leases	....	....	....	....	....	....	4·49	5,540,872·50	731,131·65	251,816·67
		Sundry claims	....	....	34·50	8·31	·10	·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	....	....	121·75	9·21	·74	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	....	....	8·00	3·41	·09	252·92	894·70	47,419·74	20,548·59	4·73
Eelya	G.M.L. 2286	Eagle Hawk	....	....	....	....	....	....	....	150·25	25·44	·73
		Voided leases	....	....	....	....	....	....	8·78	2,477·75	2,228·56	....
			....	....	....	....	....	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	2287	Rand, No. 3	....	....	256·00	49·00	2·61	....	....	256·00	49·00	2·61
		Voided leases	....	....	....	....	....	2·82	219·70	279,693·43	240,349·10	20,467·28
		Sundry claims	....	....	....	....	....	170·71	137·16	7,295·00	2,690·88	1·24
Tuckabianna	2237	Gidgie	....	....	152·50	26·57	·79	....	297·73	3,102·65	2,183·38	36·23
		Voided leases	....	....	....	....	....	649·70	996·22	13,968·23	7,833·32	4·05
		Sundry claims	7·95	....	209·50	20·22	·97	162·21	489·40	5,777·35	2,810·85	1·32
Tuckanarra	....	Voided leases	....	....	....	....	....	85·37	3,511·10	19,490·00	22,828·99	172·77
		Sundry claims	....	....	6·00	1·83	....	115·23	797·89	10,196·82	10,313·22	·13
Weld Range	....	Voided leases	....	....	....	....	....	....	23·64	2,169·75	1,137·11	....
		Sundry claims	....	....	....	....	....	....	3·90	1,438·50	1,136·41	....

		From District generally :—										
		Sundry Parcels treated at :—										
		J. & V. Hronsky & Son (L.T.T. 1467H)	....	....	....	*71·04	225·86	....	....	....	*108·28	274·87
		A. L. Armstrong (L.T.T. 1450H)	....	....	....	....	....	....	....	....	*78·01	2·60
		A. L. Armstrong (L.T.T. 1425H)	....	....	....	....	....	....	....	....	*109·35	....
		A. L. Armstrong (L.T.T. 1427H)	....	....	....	....	....	....	....	....	*107·79	23·02
		State Battery, Cue	....	....	....	26·06	3·54	....	....	76·25	26,818·66	127·53
		State Battery, Tuckanarra	....	....	....	....	....	....	....	518·50	5,535·57	....
		Various Works	....	....	....	....	....	....	....	8,097·02	30,177·79	1,206·50
		Reported by Banks and Gold Dealers	5·59	....	....	....	·02	3,441·35	109·87	....	22·62	·65
		Total	**13·54**	....	**788·25**	**215·65**	**234·72**	**5,121·73**	**9,104·99**	**6,813,672·56**	**1,402,082·41**	**274,386·08**

MEEKATHARRA DISTRICT.

Abbots	....	Voided leases	....	....	....	....	....	....	26·45	36,841·35	38,775·28	....
		Sundry claims	....	....	....	....	....	....	5·29	3,951·57	2,357·54	....
Burnakura	....	Voided leases	....	....	....	....	....	....	3,247·59	39,387·45	30,920·76	26·90
		Sundry claims	....	....	....	....	....	17·03	129·24	2,486·55	1,310·84	1·54
Chesterfield	....	Voided leases	....	....	....	....	....	29·02	420·32	11,987·26	8,656·61	25·84
		Sundry claims	....	....	....	....	....	....	42·19	1,069·05	776·69	....
Gabanintha	G.M.L. 1990N	Tumbulgum	....	....	....	....	....	....	....	188·25	49·09	4·72
	1986N	Tumbulgum North	....	....	....	....	....	....	....	161·00	92·18	9·92
		Voided leases	....	....	....	....	....	11·79	38·14	32,995·35	22,204·79	815·57
		Sundry claims	....	....	112·50	20·05	1·55	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	....
Holdens	....	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	1991N	Commodore	....	....	17·00	5·68	·23	....	....	37·00	45·79	·23
	2000N	Halcyon	....	....	763·00	40·60	1·51	....	....	763·00	40·60	1·51
	1559N	Ingliston	....	....	56·00	9·54	·32	....	498·32	3,223·85	1,895·45	·32
	1999N	Ingliston South	....	....	....	....	....	....	....	82·50	11·88	·58
	1529N	Prohibition	....	....	1,438·75	139·45	2·51	....	....	8,452·00	2,374·96	9·93
	1529N	Prohibition Gold Mine Co. N.L.	....	....	....	....	....	....	....	24,844·25	4,978·31	11·83
		Prior to transfer to present holders	....	....	....	....	....	....	....	29,422·00	4,971·30	....
	R.C. 75N	C. J. S. White & W. E. Fisher....	....	....	....	....	....	173·82	43·80	372·50	131·88	....
		Voided leases	....	....	....	....	....	7·57	1,664·22	1,717,399·07	929,181·16	2,472·84
		Sundry claims	....	....	212·00	19·20	·32	279·84	1,009·74	31,797·45	11,643·68	4·41

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 1963					Total Production				
			Alluvial	Dollied and Specimens	Ore treated	Gold therefrom	Silver	Alluvial	Dollied and Specimens	Ore treated	Gold therefrom	Silver
			Fine ozs.	Fine ozs.	Tons (2,240 lb.)	Fine ozs.	Fine ozs.	Fine ozs.	Fine ozs.	Tons (2,240 lb.)	Fine ozs.	Fine ozs.
		MURCHISON GOLDFIELD—continued. MEEKATHARRA DISTRICT—*continued.*										
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	....	....	17·00	32·05	2·10	....	....	17·00	32·05	2·10
Nannine	....	Voided leases	....	....	....	....	....	47·31	844·02	129,492·88	76,482·78	167·45
		Sundry claims	....	....	22·50	59·01	4·43	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	....
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	....	....	188·50	14·97	·53	....	....	10,519·50	3,041·77	2·57
		Voided leases	....	....	....	....	....	19·03	1,972·23	28,175·54	14,609·36	8·68
		Sundry claims	....	....	75·50	6·34	·22	61·89	647·51	11,688·67	5,117·67	·93
	From District generally :—											
	Sundry Parcels treated at :—											
		F. M. Scott (L.T.T. 1506H)	....	....	12·50	60·25	9·35	....	....	12·50	60·25	9·35
		Hanley & Christie (L.T.T. 1N/60)	....	....	....	....	....	....	....	234·00	9·69	....
		P. Polletti (L.T.T. 2N/59)	....	....	....	....	....	....	....	13·50	4·82	....
		State Battery, Meekatharra	....	....	63·00	83·60	·79	....	....	193·00	*28,021·73	25·13
		Various Works	....	....	....	....	....	....	....	3,699·80	13,948·46	391·20
		Reported by Banks and Gold Dealers	5·56	....	....	....	·43	12,253·35	185·53	451·50	97·71	1·76
		Total	**5·56**	....	**2,978·25**	**490·74**	**24·29**	**14,643·79**	**18,260·03**	**2,311,480·56**	**1,308,729·70**	**5,197·20**
		DAY DAWN DISTRICT.										
Day Dawn	G.M.L. 573D. etc.	Mountain View Gold Mine N.L.	....	....	....	....	....	....	....	13,612·10	17,376·85	217·6
		Prior to transfer to present holders	....	....	....	....	....	....	94·05	10,060·78	32,623·97	 0

	(576D)	New Fingall	....	....	....	....	....	6·12	6·84	3,230·00	1,226·01	....
		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	....	....	60·00	6·86	·22	59·07	965·49	3,663·19	1,360·99	4·98
Mainland	....	Voided leases	....	....	....	....	....	·41	3,296·77	7,575·62	25,026·07	....
		Sundry claims	....	....	....	....	....	17·85	771·56	1,337·95	701·31	....
Pinnacles	G.M.L. 664D	Eclipse	....	....	....	....	....	....	....	282·75	29·73	....
	676D	Eclipse Amalgamated, North	....	....	....	....	....	....	....	187·50	17·68	....
	670D	Eclipse North	....	....	....	....	....	....	....	840·00	47·62	....
		Voided leases	....	....	....	....	....	4·90	1,213·68	18,280·00	9,915·71	....
		Sundry claims	....	....	....	....	....	62·93	509·50	4,678·17	1,801·29	....
	From District generally :—											
	Sundry Parcels treated at :—											
	V. Hronksy (L.T.T. 1441H)		....	....	....	....	....	....	....	....	1·51	·59
	F. W. Turner (L.T.T. 1418H)		....	....	....	....	....	....	....	....	7·13	....
	Various Works		....	....	....	....	....	....	16·61	988·00	1,988·33	....
	Reported by Banks and Gold Dealers		....	....	....	....	....	2,223·83	37·47	....	12·57	·01
		Total	....	....	**60·00**	**6·86**	**·22**	**3,245·17**	**11,341·80**	**2,037,357·13**	**1,375,560·86**	**169,436·51**
		MOUNT MAGNET DISTRICT.										
Jumbulyer	G.M.L. 1410M	Gold Bug	....	....	....	....	....	....	2·20	927·35	277·15	....
		Voided leases	....	....	....	....	....	....	13·37	680·10	361·74	....
		Sundry claims	....	....	....	....	....	20·32	116·27	1,216·70	886·47	....
Lennonville	1566M	Empress	....	....	....	....	....	....	....	....	*9·51	....
	1637M	Long Reef South	....	....	....	....	....	....	....	224·75	230·27	9·69
	1651M	Nodoe	....	....	....	....	....	....	....	84·50	96·96	2·63
	1596M	Wheel of Fortune South	....	....	....	....	....	....	....	18·00	51·37	....
		Voided leases	....	....	....	....	....	....	3,226·91	151,502·55	128,568·28	459·62
		Sundry claims	....	....	135·00	15·37	·58	26·00	108·82	15,370·52	5,989·43	8·83
Mt. Magnet	1527M	Eclipse Gold Mine N.L.	....	12·20	4,449·00	4,555·09	742·29	....	12·20	36,408·00	41,852·01	4,618·48
	1527M	Eclipse	....	....	....	....	....	....	....	272·10	141·41	1·34
	1255M	Edward Carson Leases	....	....	....	....	....	1·82	....	18,042·75	12,899·55	7·76
	1455M	Evening Star	....	....	....	....	....	....	....	1,083·25	124·35	....
	1581M	Exchange	....	....	....	....	....	....	....	22·00	29·36	....
	1287M	Havelock	....	....	....	....	....	....	11·05	4,332·50	840·14	....
	1282M, etc.	Hill 50 Gold Mine N.L.	....	....	162,558·00	78,196·24	5,544·75	....	....	2,020,081·40	1,022,243·79	433,32·05
	1246M	Neptune	....	....	....	....	....	....	829·41	8,787·65	4,122·61	·21
	1361M	Jupiter	....	....	....	....	....	....	·83	658·05	261·71	....
	1444M	Late Comer	....	....	....	....	....	....	2·53	511·00	391·31	....
	1447M	Morning Star	....	....	....	....	....	....	....	2,135·40	483·54	1·53
	1475M	Morning Star North	....	....	....	....	....	....	....	11·75	8·13	....
	1536M	Pat O'Meara	....	....	....	....	....	....	....	34·00	·68	....
	1505M	Perseverance	....	....	....	....	....	....	....	107·25	11·40	....
	1654M	Susan Jane	....	....	8·00	13·71	·45	....	....	8·00	13·71	·45
	1588M	Three Boys	....	11·11	....	....	1·11	....	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	....	....	106·00	4·74	·21	157·95	2,626·24	61,253·92	30,009·04	14·73

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 1963: Alluvial	Total for 1963: Dollied and Specimens	Total for 1963: Ore treated	Total for 1963: Gold therefrom	Total for 1963: 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.										
		MOUNT MAGNET DISTRICT—*continued.*										
Mt. Magnet East	....	Voided leases	....	....	....	....	....	63·29	764·53	5,522·28	2,811·75	....
		Sundry claims	....	....	....	....	....	....	37·22	418·25	428·29	....
Moyagee	1538M	Moyagee	....	....	....	....	....	....	....	33·75	34·88	....
		Voided leases	....	....	....	....	....	....	23·59	12,439·10	18,299·16	757·77
		Sundry claims	....	....	....	....	....	14·44	176·21	1,550·75	1,752·39	....
Paynesville	....	Voided leases	....	....	....	....	....	....	1,613·34	449·77	1,116·15	....
		Sundry claims	....	....	....	....	....	3·36	540·21	882·57	1,372·00	....
Winjangoo	....	Voided leases	....	....	....	....	....	·99	202·16	366·25	99·08	1·51
		Sundry claims	....	....	....	....	....	....	223·32	237·53	71·58	....
	From District generally :—											
		Sundry Parcels treated at :—										
		P. Sciarisa (L.T.T. 1447H)	....	....	....	*159·58	12·07	....	....	·25	*269·14	19·72
		R. F. Johns & D. Budge (L.T.T. 1M/1961)	....	....	....	....	....	....	....	37·25	*27·41	2·28
		R. G. Giles (L.T.T. 1486H)	....	....	....	....	....	....	....	7·00	1·82	·16
		State Battery, Boogardie	....	....	....	....	....	....	....	348·26	*35,102·45	15·62
		Various Works	....	....	....	....	....	....	....	56·06	*18,949·24	10·04
		Reported by Banks and Gold Dealers	·28	....	....	....	....	2,317·80	114·69	8·00	113·15	·26
		Total	**·28**	**23·31**	**167,256·00**	**82,944·73**	**6,301·46**	**2,635·23**	**20,467·75**	**3,180,616·37**	**1,643,141·14**	**50,117·18**

Yalgoo Goldfield.

Mining Centre	Number of Lease	Registered Name of Company or Lease	Total for 1963: Alluvial	Total for 1963: Dollied and Specimens	Total for 1963: Ore treated	Total for 1963: Gold therefrom	Total for 1963: Silver	Total Production: Alluvial	Total Production: Dollied and Specimens	Total Production: Ore treated	Total Production: Gold therefrom	Total Production: Silver
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	....
Field's Find	G.M.L. 1207	Rose Marie	....	....	....	....	....	....	....	418·67	254·46	1·59
		Voided leases	....	....	....	....	....	....	226·72	50,316·71	33,692·51	58·08
		Sundry claims	....	....	....	....	....	5·77	188·67	5,558·85	1,783·13	·15
Goodingnow	1063	Ark	....	....	....	....	....	....	12·49	2,270·50	1,927·29	....
		Voided leases	....	....	....	....	....	146·70	299·28	81,813·71	66,366·75	·68
		Sundry claims	....	....	....	....	....	152·96	169·70	10,433·05	5,136·08	·14
Gullewa	....	Voided leases	....	....	....	....	....	....	19·05	39,913·60	20,966·51	113·70
		Sundry claims	....	....	....	....	....	....	170·45	4,391·25	1,918·24	....

Kirkalucka	....	Voided leases	....	....	....	....	....	....	....	61·25	45·10	....
		Sundry claims	....	....	....	....	....	....	17·79	257·30	126·29	....
Messenger's Patch	1237	Gnow's Nest	....	....	....	§20·73	....	....	....	....	§20·73	....
		Voided leases	....	....	....	....	....	8·64	349·71	39,836·51	28,564·95	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	1201	Hard to Find	....	....	....	....	....	....	....	114·00	111·83	....
		Voided leases	....	....	....	....	....	7·88	31·96	11,149·75	5,659·83	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
Wardawarra	....	Voided leases	....	....	....	....	....	....	....	10,760·50	5,862·04	....
		Sundry claims	....	....	161·50	80·22	6·22	....	....	1,108·75	508·63	8·53
Warriedar	....	Voided leases	....	....	....	....	....	....	....	13,661·50	4,607·88	7·30
		Sundry claims	....	....	....	·17	·02	....	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 Goldfields generally :—										
		Sundry Parcels treated at :—										
		Francis & Latham (L.T.T. 1463H)	....	....	....	....	....	....	....	....	*·98	·17
		State Battery, Payne's Find	....	....	....	....	....	....	....	156·50	*4,548·42	....
		State Battery, Warriedar	....	....	....	....	....	....	....	....	*6,545·96	·90
		State Battery, Yalgoo	....	....	....	....	....	....	....	....	*1,200·51	....
		Various Works	....	....	....	....	....	9·42	....	865·00	*3,337·19	99·84
		Reported by Banks and Gold Dealers	·36	....	....	....	....	964·80	58·32	....	48·90	·89
		Total	**·36**	....	**161·50**	**101·12**	**6·24**	**1,808·38**	**3,223·19**	**443,349·58**	**264,036·39**	**1,522·41**

Table I.—*Production of Gold and Silver from all sources, etc.*—continued.

Mt. Margaret Goldfield.

MOUNT MORGANS DISTRICT.

Mining Centre	Number of Lease	Registered Name of Company or Lease	Total for 1963					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.
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	....
Linden	....	Voided leases	....	....	....	....	....	7·53	566·97	72,919·81	66,208·35	·68
		Sundry claims	....	....	32·00	16·73	·40	132·11	244·96	19,607·35	13,839·10	·40
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	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	....	....	107·00	70·55	6·31	51·15	557·24	6,798·68	4,778·87	15·60
Redcastle	....	Voided leases	....	....	....	....	....	4·49	491·33	4,284·95	4,111·85	....
		Sundry claims	....	....	....	....	....	....	113·84	1,183·57	642·45	....
Yundamindera	....	Voided leases	....	....	....	....	....	....	110·93	84,523·85	52,042·94	36·50
		Sundry claims	....	....	....	....	....	3·01	271·93	6,674·35	4,789·46	....
	From District generally :—											
	Sundry Parcels treated at :											
	Crocker's Anniversary Battery		....	....	....	....	....	....	....	10·00	§26·96	....
	United Aborigine's Mission		....	....	....	....	....	113·08	18·87	403·00	135·50	·09
	State Battery, Linden		....	....	....	....	....	....	9·16	299·54	*15,502·97	....
	Various Works		....	....	....	....	....	....	....	1,257·81	*8,561·39	99·97
	Reported by Banks and Gold Dealers		9·89	....	....	....	....	3,157·72	141·84	10·30	95·75	·68
		Total	**9·89**	....	**139·00**	**87·28**	**6·71**	**3,571·23**	**9,398·51**	**1,217,696·31**	**717,905·54**	**5,828·32**

MOUNT MALCOLM DISTRICT.

Mining Centre	Number of Lease	Registered Name of Company or Lease	Alluvial	Dollied and Specimens	Ore treated	Gold therefrom	Silver	Alluvial	Dollied and Specimens	Ore treated	Gold therefrom	Silver
Cardinia	....	Voided leases	....	....	....	....	....	13·87	1,598·15	5,531·74	4,238·57	....
		Sundry claims	....	....	....	....	....	4·25	121·91	1,948·25	643·86	2·87
Diorite	....	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	....	....	1,917·75	125·08	3·87	....	....	6,937·75	537·18	6·53
		Voided leases	....	....	....	....	....	....	4,482·18	74,717·46	52,293·77	7·56
		Sundry claims	....	....	222·00	261·27	20·68	129·92	906·52	11,892·62	6,559·42	29·87
Leonora	1829C	Jessie Alma	....	....	....	....	....	....	582·87	727·25	1,920·53	....
	1849C	Puzzle	....	....	37·00	44·16	2·76	....	....	64·00	97·46	3·11
	1579C, etc.	Sons of Gwalia Ltd.	....	....	159,651·00	31,343·96	2,859·89	....	....	7,030,740·53	2,580,411·45	188,738·17
		Prior to transfer to present holders	....	....	....	....	....	....	....	109,081·00	55,989·21	8·66
	1848C	Tower Hill	....	....	315·00	61·74	3·49	....	....	1,434·75	191·63	8·83
	1847C	Victor	....	....	12·00	8·52	·35	....	2·34	28·50	42·25	·44
		Voided leases	....	....	....	....	....	....	1,866·86	176,575·00	91,197·84	94·57
		Sundry claims	....	....	240·00	37·65	1·51	37·73	377·26	21,861·95	12,641·45	20·15
Malcolm	....	Voided leases	....	....	....	....	....	11·65	47·07	62,656·53	47,563·43	....
		Sundry claims	....	....	....	....	....	5·75	35·60	4,948·47	2,728·98	1·59
Mertondale	....	Voided leases	....	....	....	....	....	....	....	89,024·75	60,935·32	1,497·58
		Sundry claims	....	....	....	....	....	5·42	85·74	3,216·41	2,295·52	....
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
Pigwell	....	Voided leases	....	....	....	....	....	....	....	13,587·32	14,676·58	63·68
		Sundry claims	....	....	....	....	....	....	34·61	2,896·65	1,225·46	....
Randwick	....	Voided leases	....	....	....	....	....	....	246·76	10,912·65	9,736·57	....
		Sundry claims	....	....	....	....	....	66·57	164·02	2,551·64	1,320·66	....
Webster's Find	....	Voided leases	....	....	....	....	....	30·30	....	22,167·50	14,377·65	....
		Sundry claims	....	....	....	....	....	36·84	695·68	2,356·15	1,530·56	....
Wilson's Creek	....	Voided leases	....	....	....	....	....	....	....	333·50	168·27	....
		Sundry claims	....	....	....	....	....	·70	4·24	316·00	261·12	....
Wilson's Patch	....	Voided leases	....	....	....	....	....	....	99·38	28,863·35	13,050·19	1·05
		Sundry claims	....	....	....	....	....	4·68	54·46	1,700·16	1,433·20	·96
	From District generally :—											
	Sundry Parcels treated at :—											
	State Battery, Darlot		....	....	....	....	....	....	....	18·00	*2,514·77	4·98
	Reefer Cyanide Plant		....	....	....	....	....	....	....	20·00	*3,125·37	22·38
	Various Works		....	....	....	....	....	....	....	789·50	*22,175·93	135·97
	Reported by Banks and Gold Dealers		2·00	....	....	....	....	3,648·05	252·83	46·50	57·80	....
		Total	**2·00**	....	**162,394·75**	**31,882·38**	**2,892·55**	**4,061·87**	**16,668·99**	**7,749,485·97**	**3,068,575·90**	**190,682·37**

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	....

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 1963					Total Production				
			Alluvial	Dollied and Specimens	Ore treated	Gold therefrom	Silver	Alluvial	Dollied and Specimens	Ore treated	Gold therefrom	Silver
			Fine ozs.	Fine ozs.	Tons (2,240 lb.)	Fine ozs.	Fine ozs.	Fine ozs.	Fine ozs.	Tons (2,240 lb.)	Fine ozs.	Fine ozs.
MOUNT MARGARET GOLDFIELD—continued.												
MOUNT MARGARET DISTRICT.												
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 :											
	United Gold Recoveries Pty. Ltd.		....	....	....	....	....	....	....	·25	*3,786·44	3,374·06
	State Battery, Laverton		....	....	....	....	....	....	....	97·50	*19,327·97	561·11
	Various Works		....	....	....	....	....	....	....	214·75	*19,403·68	·24
	Reported by Banks and Gold Dealers		....	....	....	....	....	2,580·75	108·08	....	29·18	....
		Total	....	....	....	....	....	**4,143·54**	**9,354·35**	**2,528,173·24**	**1,174,043·56**	**66,190·70**

North Coolgardie Goldfield.

MENZIES DISTRICT.

Mining Centre	Number of Lease	Registered Name of Company or Lease	Alluvial	Dollied and Specimens	Ore treated	Gold therefrom	Silver	Alluvial	Dollied and Specimens	Ore treated	Gold therefrom	Silver
Comet Vale	G.M.L. 5766Z	Coonega Extended	....	....	....	....	....	....	....	100·25	35·55	....
		Voided leases	....	....	....	....	....	....	419·74	267,668·97	193,272·82	5,355·33
		Sundry claims	....	....	....	....	....	....	40·19	2,236·96	1,176·14	....
Goongarrie	5740Z	Gull's Blow	....	....	17·25	8·31	....	....	164·75	374·75	265·78	....
		Voided leases	....	....	....	....	....	·94	1,385·26	29,897·79	18,124·83	....
		Sundry claims	....	3·61	10·25	8·63	....	46·46	2,144·42	2,888·10	3,383·37	....

Menzies	5793Z	Black Swan	....	....	473·75	33·50	....	....	....	473·75	33·50	....
	5511Z	First Hit	....	....	465·25	90·18	....	....	....	6,911·00	7,743·80	22·37
	5511Z	First Hit Gold Mines (1934) Ltd.	....	....	....	....	....	....	....	68,473·70	49,060·96	6,676·23
	5788Z	Flying Fish	....	....	110·75	6·90	....	....	....	291·25	43·38	....
	5542Z	Good Block Lease	....	....	49·65	6·17	....	....	7·32	3,550·05	3083·09	....
	5780Z	Good Enough	....	....	497·25	48·04	....	....	....	3,740·70	1,030·51	1·54
	5795Z	Little Wonder	....	....	75·00	10·98	....	....	....	75·00	10·98	....
	5520Z	Mignonette	....	....	....	....	....	....	....	808·50	404·43	....
		Voided leases	....	....	....	....	....	45·42	1,260·24	939,406·13	729,011·90	13,595·47
		Sundry claims	....	....	594·50	99·90	....	56·87	624·33	39,635·59	26,285·08	812·86
Mt. Ida	5701Z, etc.	Moonlight Wiluna G.M. Ltd.	....	....	28,914·00	14,633·11	344·94	....	40·77	369,471·86	192,327·87	1,257·16
		Prior to transfer to present holders	....	....	....	....	....	....	....	31,883·25	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 :											
	R. McPherson (L.T.T. 3Z/59)		....	....	....	....	....	....	....	....	*15·20	....
	R. H Bennetts (L.T.T. 1423H)		....	....	....	....	....	....	....	79·50	31·83	....
	State Battery Mt. Ida		....	....	....	....	....	....	....	1,866·25	*7,556·16	2·04
	State Battery, Menzies		....	....	....	*314·62	230·12	....	....	....	*3,693·67	957·43
	Various Works		....	....	....	....	....	....	....	3,136·55	*58,757·09	3,062·11
	Reported by Banks and Gold Dealers		5·62	....	....	....	....	1,495·49	403·22	100·00	48·49	....
		Total	**5·62**	**3·61**	**31,207·64**	**15,260·34**	**575·06**	**1,693·32**	**7,018·53**	**1,858,566·33**	**1,393,042·05**	**32,740·66**

ULARRING DISTRICT.

Davyhurst	....	Voided Leases	....	....	....	....	....	2·3	152·64	304,354·62	195,751·92	21,336·15
		Sundry Claims	....	....	....	....	....	....	208·48	14,160·19	5,787·29	....
Morleys	G.M.L. 1094U	First Hit	....	....	217·25	137·38	1·65	....	....	5,219·25	7,154·27	11·40
	1168U	Hazel Dawn	....	....	....	....	....	....	....	51·25	104·97	....
	1081U	Mabel Gertrude	....	....	27·75	19·28	....	....	17·19	1,720·50	2,017·34	....
	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	....
	1173U	Riverina	....	....	....	....	....	....	....	29·50	23·51	....
	1070U	(Riverina)	....	....	....	....	....	....	....	283·00	75·30	....
	1068U	Riverina Gold Mines Pty. Ltd.	....	....	....	....	....	....	....	32,085·50	11,669·45	·07
	1176U	Wild Cat	....	....	60·50	59·98	....	....	....	278·75	240·40	....
		Voided Leases	....	....	....	....	....	....	274·09	103,441·57	105,649·51	530·75
		Sundry Claims	....	....	39·75	113·17	....	10·82	296·42	11,195·64	9,881·49	1·10
Mulwarrie	1153U	Fourmile	....	....	4·00	41·23	....	....	....	93·00	540·15	....
	1113U	Oakley	....	....	182·00	283·12	36·39	....	....	4,602·00	6,813·61	83·68
		Voided Leases	....	....	....	....	....	....	165·29	19,480·68	26,369·21	38·47
		Sundry Claims	....	....	....	....	....	·80	282·29	3,106·33	2,722·13	....

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 1963					Total Production				
			Alluvial	Dollied and Specimens	Ore treated	Gold therefrom	Silver	Alluvial	Dollied and Specimens	Ore treated	Gold therefrom	Silver
			Fine ozs.	Fine ozs.	Tons (2,240 lb.)	Fine ozs.	Fine ozs.	Fine ozs.	Fine ozs.	Tons (2,240 lb.)	Fine ozs.	Fine ozs.
		NORTH COOLGARDIE GOLDFIELD—continued.										
		ULARRING DISTRICT—*continued.*										
Ularring	....	Voided Leases	....	....	....	....	....	....	563·34	9,771·60	13,907·76	....
		Sundry Claims	....	....	....	....	....	....	....	671·50	309·48	....
		From District Generally :—										
		Sundry Parcels treated at :										
		State Battery, Mulline	....	....	....	....	....	....	....	639·99	*16,459·89	....
		State Battery, Mulwarrin			....	....	....	....	....	613·18	*6,564·16	....
		Linnett & Hawkins (L.T.T. 1252H)	....	....	....	....	....	....	....	....	*229·52	1·53
		Riverina, South Battery	....	....	....	....	....	....	....	....	*900·46	....
		Various Works	....	....	....	....	....	....	15·82	268·15	9,639·15	11·15
		Reported by Banks and Gold Dealers	....	....	....	....	....	112·81	424·28	100·00	106·34	....
		Total	....	....	**531,25**	**654·16**	**38·04**	**129·52**	**7,216·11**	**534,411·20**	**444,456·65**	**22,024·48**
		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	....	....	1,019·50	377·66	8·06	....	....	13,196·25	7,597·37	24·80
	940G	New Gladstone	....	....	55·00	7·59	·12	....	....	381·25	69·03	·20
		Voided Leases	....	....	....	....	....	3·35	347·30	748,602·71	396,353·94	5,376·87
		Sundry Claims	....	....	25·75	16·41	·29	60·92	106·60	9,462·80	6,960·91	4·19
Niagara	....	Voided Leases	....	....	....	....	....	....	104·54	85,876·50	52,365·05	....
		Sundry Claims	....	....	....	....	....	28·10	97·22	14,687·91	8,265·87	....
Tampa	....	Voided Leases	....	....	....	....	....	....	41·58	50,477·57	23,287·71	174·24
		Sundry Claims	....	....	....	....	....	32·60	283·40	8,041·33	4,113·02	....
		From District Generally :—										
		Sundry Parcels treated at :—										
		Various Works	....	....	....	....	....	....	....	1,220·50	20,884·22	120·98
		Reported by Banks and Gold Dealers	....	....	....	....	....	1,593·39	823·66	....	63·53	....
		Total	....	....	**1,100·25**	**401·66**	**8·47**	**1,718·36**	**1,821·77**	**943,981·27**	**528,408·94**	**5.713·32**
		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	....

Pingin	....	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	....	....	84·00	16·07	....	....	....	90·50	19·03	....
	1320R	Margaret	....	....	235·00	15·98	....	....	....	4,606·00	1,318·59	·32
	1126R, etc.	Porphyry (1939) Gold Mines N.L.	....	....	....	....	....	....	....	66,939·00	9,893·51	261·95
	1136R, etc.	(Edjudina Gold Mining Co. N.L.)	....	....	....	....	....	....	....	30,220·00	5,409·93	507·51
		Prior to transfer to present holders	....	....	....	....	....	....	....	124·50	38·89	....
	1345R	Wallaby Extended	....	....	90·00	4·41	....	....	....	146·00	11·47	....
	1339R	Yilgangie	....	....	136·00	37·87	....	....	....	725·00	274·09	·46
		Voided Leases	....	....	....	....	....	6·30	87·08	45,427·75	21,392·94	2·00
		Sundry Claims	....	....	75·00	31·07	....	·87	5·93	18,088·05	6,340·30	1·27
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, etc.	Western Mining Corporation	....	....	1,469·00	1,924·06	244·70	....	....	31,157·50	29,333·18	4,303·43
		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
	State Battery, Yerilla		....	....	....	....	....	....	....	....	*43·52	....
	Various Works		....	....	....	....	....	2·17	....	642·25	*6,049·24	....
	Reported by Banks and Gold Dealers		....	....	....	1·44	0·09	116·60	160·08	....	28·80	·09
		Total	....	....	**2,089·00**	**2,030·90**	**244·79**	**1,311·91**	**3,817·12**	**294,538·78**	**176,971·62**	**5,167·12**

Broad Arrow Goldfield.

Bardoc	....	Voided Leases	....	....	....	....	....	....	2,335·41	85,370·59	55,699·50	203·60
		Sundry Claims	....	....	89·25	15·98	....	54·95	1,218·09	17,873·03	8,349·95	....
Black Flag	G.M.L. 2229W	Bellevue	....	....	33·00	12·67	....	....	212·68	4,102·23	3,243·52	9·76
	2291W	Bellevue South	....	....	48·75	8·32	....	....	....	99·75	11·61	·07
		Voided Leases	....	....	....	....	....	27·81	405·90	48,277·79	28,175·08	....
		Sundry Claims	....	....	....	....	....	712·92	251·59	8,337·01	5,020·54	....
Broad Arrow	....	Voided Leases	....	....	....	....	....	70·32	10,453·81	155,895·94	120,088·05	20·23
		Sundry Claims	....	....	231·50	104·17	....	1,007·72	3,046·26	35,671·65	17,286·41	·48
Cane Grass	....	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

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 1963					Total Production				
			Alluvial	Dollied and Specimens	Ore treated	Gold therefrom	Silver	Alluvial	Dollied and Specimens	Ore treated	Gold therefrom	Silver
			Fine ozs.	Fine ozs.	Tons (2,240 lb.)	Fine ozs.	Fine ozs.	Fine ozs.	Fine ozs.	Tons (2,240 lb.)	Fine ozs.	Fine ozs.
		BROAD ARROW GOLDFIELD—continued.										
Christmas Reef	2279W	New Mexico	....	....	50·00	18·91	....	....	....	673·75	494·90	6·99
	2253W	New Mexico South	....	....	87·50	17·11	....	....	....	3,352·28	3,534·94	·57
		Voided Leases	....	....	....	....	....	....	55·49	1,865·12	3,606·65	....
		Sundry Claims	....	....	3·00	1·23	....	....	441·85	3,330·64	3,249·25	....
Fenbark	....	Voided Leases	....	....	....	....	....	....	4·42	6,771·00	2,711·68	....
		Sundry Claims	....	....	....	....	....	....	51·96	3,031·52	1,000·47	....
Grant's Patch	2311W	Bent Tree	....	....	....	....	....	....	....	128·00	75·17	....
	2277W	Coronation	....	....	28·50	22·94	....	....	....	564·25	471·22	1·39
	2278W	Prince of Wales Syndicate	....	....	57·50	97·30	....	....	....	760·25	1,343·64	40·88
	2278W, 2277W	(Ora Banda Amalgamated Mines N.L.)	....	....	....	....	....	....	....	961·00	1,148·58	....
	2299W	Jeanie May	....	....	45·00	6·26	....	....	....	45·00	6·26	....
		Voided Leases	....	....	....	....	....	....	274·13	204,038·59	80,138·34	175·00
		Sundry Claims	....	....	88·75	15·56	....	....	356·66	7,353·09	3,232·26	....
Ora Banda	G.M.L. 2270W, etc.	Gimlet South Leases	....	....	6,184·50	430·39	....	....	....	18,088·75	2,768·76	·06
	2300W	Sleeping Beauty	....	....	869·50	192·46	....	....	....	3,000·00	948·62	1·14
		Voided Leases	....	....	....	....	....	....	846·13	423,666·52	151,214·10	1,685·77
		Sundry Claims	....	....	460·50	37·20	....	....	467·18	15,858·30	4,915·26	....
Paddington	2298W	Rona Lucille	....	....	....	....	....	....	....	227·50	40·46	....
		Voided Leases	....	....	....	....	....	5,566·30	463·31	196,486·56	86,485·99	32·15
		Sundry Claims	....	....	53·25	9·74	....	1,714·16	291·43	17,532·93	9,320·21	....
Riche's Find	2306W	Cave Hill	....	....	12·25	10·34	....	....	238·15	58·85	110·91	....
		Voided Leases	....	....	....	....	....	....	21·64	7,643·09	6,095·69	71·36
		Sundry Claims	....	....	64·50	15·69	....	....	549·09	2,044·00	2,509·62	·13
Siberia	....	Voided Leases	....	....	....	....	....	1·07	2,649·28	28,995·47	31,776·06	....
		Sundry Claims	....	....	10·00	1·50	....	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 :										
		H. L. S. Seaton & H. E. Edwards (L.T.T. 1W/62)	....	....	....	....	....	....	....	....	*12·00	....
		W. J. Ferguson (L.T.T. 1455H)	....	....	....	....	....	....	....	·50	·52	....
		H. T. Kingdon (M.A. 4W)	....	....	....	....	....	....	1·53	12·55	6·49	·18
		State Battery, Ora Banda	....	....	....	260·78	·24	....	....	128·05	*26,887·54	

		Golden Arrow Battery	....	....	....	....	....	....	....	80·75	*4,333·07	2·30
		Various Works	....	....	....	....	....	2,275·66	1·24	16,967·02	*49,504·77	3,103·45
		Reported by Banks and Gold Dealers	6·59	....	....	....	....	10,024·93	165·70	61·68	95·83	·15
		Total	**6·59**	....	**8,417·25**	**1,278·55**	**·24**	**21,988·45**	**27,995·95**	**1,371,960·26**	**743,856·60**	**5,429·59**

North-East Coolgardie Goldfield.

KANOWNA DISTRICT.

Gindalbie	1583X	S.H.E.	....	....	26·25	16·99	·10	....	....	269·25	180·24	·10
		Voided Leases	....	....	....	....	....	....	1,151·99	46,180·53	41,748·13	38·31
		Sundry Claims	....	....	....	....	....	....	716·52	5,857·27	3,309·40	·01
Gordon	....	Voided Leases	....	....	....	....	....	....	682·54	53,900·58	20,072·51	517·61
		Sundry Claims	....	....	....	....	....	....	177·38	2,265·95	1,229·87	....
Kalpini	....	Voided leases	....	....	....	....	....	....	38·73	13,543·50	6,753·78	·07
		Sundry claims	....	....	....	....	....	24·70	269·72	1,492·50	1,026·37	....
Kanowna	G.M.L. 1572X	Kanowna Red Hill	....	....	80·00	27·84	....	....	2·38	3,588·75	1,184·19	4·60
		Voided leases	....	....	....	....	....	24·94	4,516·76	685,625·60	380,504·87	2,482·24
		Sundry claims	....	....	183·75	26·67	....	125·32	2,169·07	28,450·82	12,120·02	1·71
Mulgarie	....	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	2·51	....	....	....	....	106,033·45	40·42	·50	109·73	....
		Total	**2·51**	....	**290·00**	**71·50**	**·10**	**106,538·83**	**13,526·67**	**1,009,633·31**	**627,293·48**	**3,044·65**

KURNALPI DISTRICT.

Jubilee	....	Voided leases	....	....	....	....	....	....	145·13	2,122·50	1,465·16	....
		Sundry claims	....	....	17·75	5·11	....	25·57	13·52	1,264·00	527·32	....
Karonie	460K	Rowe's Find	....	....	152·00	84·12	....	....	....	152·00	84·12	....
		Sundry claims	....	....	132·50	60·80	....	....	....	132·50	60·80	....
Kurnalpi	....	Voided leases	....	....	....	....	....	371·18	3,166·80	4,130·76	4,022·13	6·27
		Sundry claims	....	....	18·00	7·60	....	324·12	727·39	4,576·11	2,363·83	....
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	1,327·45	2,241·18	....

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 1963					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.
NORT-EAST COOLGARDIE GOLDFIELD—continued.												
KURNALPI DISTRICT—continued.												
		From District generally :—										
		Sundry Parcels treated at :—										
		Various Works	....	....	....	....	....	....	....	101·50	388·63	....
		Reported by Banks and Gold Dealers	....	....	....	....	....	12,107·71	70·70	....	2·35	1·49
		Total	....	....	**320·25**	**157·63**	....	**12,836·64**	**8,298·91**	**14,103·57**	**19,008·11**	**12·71**

East Coolgardie Goldfield.

EAST COOLGARDIE DISTRICT.

Mining Centre	Number of Lease	Registered Name of Company or Lease	Alluvial (1963)	Dollied and Specimens (1963)	Ore treated (1963)	Gold therefrom (1963)	Silver (1963)	Alluvial (Total)	Dollied and Specimens (Total)	Ore treated (Total)	Gold therefrom (Total)	Silver (Total)
Binduli	....	Voided leases	....	....	....	....	....	....	....	1,904·60	495·36	....
		Sundry claims	....	....	93·25	8·80	....	....	13·01	5,790·62	1,740·08	·08
Boorara	....	Voided leases	....	....	....	....	....	....	459·07	309,467·82	172,861·95	411·37
		Sundry claims	....	....	....	....	....	·49	145·56	4,251·34	1,570·80	·05
Boulder	G.M.L. 6145E	Boomerang	....	....	....	....	....	....	....	77·00	8·00	....
	5531E	Cassidy's Hill	....	....	142·75	18·36	....	....	....	1,508·50	134·31	....
	5964E	Croesus Extended	....	....	....	....	....	....	....	192·75	16·57	....
	6537E	Golden Key	....	....	....	....	....	....	58·22	767·10	828·68	....
	5692E, etc.	Gold Mines of Kalgoorlie (Aust.) Ltd.	....	....	517,958·00	138,187·54	39,412·16	....	....	3,533,517·00	941,147·76	212,661·52
		Prior to transfer to present holders	....	....	....	....	....	....	791·73	15,916,155·97	6,415,881·49	819,123·27
	5696E, etc.	Great Boulder Gold Mines Ltd.	....	....	450,249·00	118,519·86	34,204·31	....	1·53	15,026,863·97	6,640,170·05	1,637,879·83
	5478E, etc.	Lake View & Star Ltd.	....	....	690,537·00	177,392·37	21,199·63	....	....	17,883,517·30	5,184,201·92	574,421·61
		Prior to transfer to present holders	....	....	....	....	....	....	8·49	15,792,500·38	9,149,223·80	1,348,055·28
	5431E, etc.	North Kalgurli (1912) Ltd.	....	....	371,967·00	85,907·76	45,534·03	....	127·55	6,832,060·24	1,822,251·79	446,997·63
	5405E, etc.	North Kalgurli (1912) Ltd. (Croesus Pty. Group)	....	....	....	....	....	....	51·20	90,159·00	19,261·22	....
	5891E	New Croesus	....	....	....	....	....	....	....	193·00	48·74	....
		Prior to transfer to present holders	....	....	....	....	....	43·99	....	4,018,436·01	2,815,911·21	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	6591E	Kalgoorlie Star	....	....	26·75	6·21	....	....	....	51·50	18·22	·57
		Voided leases	....	....	....	....	....	....	110·93	863·30	425·16	....
		Sundry claims	....	....	87·50	4·63	....	....	199·00	1,352·25	659·83	....
Hampton Plains	P.P.1	Hampton Boulder	....	....	....	....	....	....	....	361·75	38·81	·08

	P.P.1, etc.	Consolidated Gold Areas N.L.	....	....	....	....	....	....	....	142,565·73	37,249·15	5,835·85
	Loc. 10. Block 50	F. C. Shoppe	....	....	....	....	....	....	....	891·50	42·05	....
	P.P. 12	Junction Extended	....	....	....	....	....	....	....	3,675·00	545·35	....
	P.P. 86	Golden Hope N.L.	....	....	....	....	....	....	....	5,964·00	2,006·14	....
	P.P. 23	A. McKay	....	....	....	....	....	....	....	80·25	5·46	....
	P.P. 23	Mutooroo	....	....	....	....	....	....	....	1,747·50	134·82	....
	P.P. 202	P. E. Dolling	....	....	....	....	....	....	....	5·25	·29	....
	P.P. 280	W. J. White	....	....	87·75	14·75	....	....	....	255·50	46·37	....
	P.P. 48	E. Doherty	....	....	....	....	....	....	....	....	34·65	....
	P.P. 175	S. Shackleton	....	....	....	....	....	....	....	121·25	7·40	....
	P.P. 175	Jubilee	....	....	....	....	....	....	....	6,708·00	906·81	....
	P.P. 192	Golden Hope North	....	....	....	....	....	....	....	353·00	201·02	....
	P.P. 222	Hampton Jubilee	....	....	....	....	....	....	....	1,247·75	99·96	·50
	P.P. 252	Hampton Properties Ltd—Mount Martin	....	....	....	....	....	....	....	14,953·75	5,574·11	....
	P.P. 227	Parker & Africh	....	....	....	....	....	....	....	630·00	37·28	....
	P.P. 277	M. Africh	....	....	2,292·75	106·36	·01	....	....	9,832·75	716·35	·01
	P.P. 277	Pernatty	....	....	....	....	....	....	....	7,247·75	866·88	·01
	P.P. 277	New Hope	....	....	....	....	....	....	17·23	61,468·55	11,175·94	....
	P.P. 460	Hampton Xmas Gift	....	....	....	....	....	6·72	37·57	107·00	89·44	....
	P.P. 471	Cullen & Renton	....	....	....	....	....	....	....	7·05	126·78	....
	P.P. 474	L. Rowell	....	....	....	....	....	....	....	20·75	3·96	....
	P.P. 476	Ivy Rose	....	....	6·50	54·29	....	....	7·75	106·05	293·10	·72
	P.P. 478	L. Bracegirdle	....	....	7·50	7·19	....	....	....	10·25	12·44	....
	P.P. 480	A. Brokenshire	....	....	....	....	....	....	....	26·50	7·73	....
		Cancelled Leases	....	....	....	....	....	4,578·52	203·94	126,877·34	39,711·84	69·83
		Sundry Claims and Leases	....	39·61	109·00	88·50	....	2·68	110·46	46,790·91	8,635·62	·13
Kalgoorlie	G.M.L. 6562E	Bretvic	....	....	....	....	....	....	....	326·50	26·09	....
	6503E	Coronation	....	....	....	....	....	....	....	20·50	2·52	....
	5510E	Golden Dream	....	....	....	....	....	....	....	207·75	19·29	....
	5510E	Golden Dream (B.H.P. Co. Ltd.)	....	....	....	....	....	....	....	530·74	149·77	....
	6563E, etc.	Champagne Syndicate N.L.	....	....	....	....	....	....	....	12,287·75	1,348·10	61·41
	4547E, etc.	Mount Charlotte (Kalgoorlie) Gold Mines Ltd.	....	....	....	....	....	....	....	25,143·25	2,888·32	110·15
		Prior to transfer to present holders	....	....	....	....	....	....	5·72	48,292·60	13,930·79	....
	6589E	Grays Central	....	....	....	....	....	....	....	822·75	153·15	....
	6502E	Gold Mines of Kalgoorlie (Aust.) Ltd.	....	....	2,337·25	432·84	....	....	....	7,077·50	1,676·49	4·31
	6502E	Western Mining Corp. Ltd.	....	....	....	....	....	....	....	256·00	65·07	4·28
	6091E	Lesanben	....	....	44·00	43·31	·48	....	193·96	1,147·80	745·10	2·93
	6485E	Maritana Hill	....	....	192·75	11·20	....	....	....	3,331·25	405·43	....
	6535E	Mary A	....	....	427·75	40·81	....	....	....	5,915·00	552·61	·14
	5852E, etc.	Pedestal Leases	....	....	....	....	....	....	....	1,828·50	490·37	....
	6024E	Trident	....	....	....	....	....	....	....	58·75	36·67	....
	5852E	Pedestal	....	....	....	....	....	....	....	1,608·75	444·93	....
		Voided Leases	....	....	....	....	....	242·48	10,802·28	1,474,617·52	582,555·68	45,975·97
		Sundry Claims	....	·37	375·25	54·21	....	232·41	1,124·98	63,233·78	23,401·57	·18
Wombola	5688E, etc.	Caledonian Leases	....	....	....	....	....	....	....	970·00	659·67	....
	5688E	Caledonian	....	....	....	....	....	....	....	4,275·00	3,632·98	....
	(5967E)	North Caledonian	....	....	....	....	....	....	1·27	22·25	8·15	....
	5497E, etc.	Daisy Leases	....	....	1,180·00	4,447·64	643·29	....	....	19,309·95	17,662·23	789·04
	5497E	Daisy	....	....	....	....	....	....	....	6,282·25	5,031·93	....
	5500E	Happy-Go-Lucky	....	....	....	....	....	....	....	2,075·25	1,675·85	....
	5689E, etc.	Mt. Monger Mining Syndicate	....	....	8·50	*4,141·27	920·33	....	....	5,022·25	7,367·15	962·05
	5689E, etc.	(Haoma Gold Mines N.L.)	....	....	....	....	....	....	....	9,233·00	7,239·42	269·03
	5689E, etc.	(Haoma Leases)	....	....	....	....	....	....	....	27,396·50	25,445·40	79·15

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 1963					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.*										
	5689E	(Haoma)	....	....	....	....	....	....	....	2,168·00	1,948·36	·54
	5525E	(Xmas Flat)	....	....	....	....	....	....	....	330·25	264·74	....
	5798E	(Maranoa)	....	....	....	....	....	....	32·17	3,183·50	1,633·27	....
	5943E	(New Milano N.L.)	....	....	....	....	....	....	·25	17,390·75	11,622·24	479·00
	5493E	(Milano)	....	....	....	....	....	....	....	4,012·75	11,676·72	....
	5616E	(Leslie)	....	....	....	....	....	....	....	602·00	939·10	....
	G.M.L. 6312E	Inverness	....	....	132·50	26·14	....	....	....	3,402·00	610·00	....
	6487E	Leslie	....	....	38·50	11·28	....	....	....	382·25	355·13	·49
	6614E	Logan's Gold Mine	....	....	130·50	18·84	....	....	....	130·50	18·84	....
	6533E	Rosemary	....	....	1,445·25	606·81	34·72	....	....	7,645·35	9,157·03	113·00
		Voided Leases	....	....	....	....	....	3·80	2,497·30	34,368·84	43,609·38	1·18
		Sundry Claims	....	....	400·25	86·65	....	....	711·10	25,929·93	14,563·30	·20
	From District Generally :—											
	Sundry Parcels treated :											
		Golden Horse Shoe (New) Ltd.	....	....	....	....	....	....	....	....	*350,028·15	354,192·20
		Bagworth & Parker (L.T.T. 1415H)	....	....	....	....	....	....	....	....	3·57	....
		Northern Mineral Sands	....	....	....	....	....	....	....	532·25	216·88	....
		State Battery, Kalgoorlie	....	....	....	750·67	115·84	....	....	390·70	37,240·07	349·65
		Sundry Claims	....	....	....	....	....	11,014·57	465·61	5,440·46	2,541·10	....
		Various Works	....	....	....	....	....	384·36	64·70	41,135·02	270,756·33	14,114·46
	Reported by Banks and Gold Dealers		6·93	....	23·25	5·82	....	17,001·87	10,073·32	415·68	7,504·35	....
		Total	**6·93**	**39·98**	**2,040,030·50**	**530,994·11**	**142,064·80**	**33,719·69**	**41,186·82**	**83,555,641·60**	**35,504,587·96**	**5,584,639·69**
		BULONG DISTRICT.										
Balagundi	....	Voided Leases	....	....	....	....	....	....	2,408·98	1,115·93	1,488·91	12·92
		Sundry Claims	....	2·20	....	....	....	3·51	295·72	806·01	505·93	....
Bulong	G.M.L. 1311Y	Blue Quartz....	....	....	....	....	....	....	....	2,031·25	701·61	....
	1337Y	Rainbow	....	....	62·50	6·74	....	....	....	351·00	46·11	....
		Voided Leases	....	....	....	....	....	107·54	8,526·12	108,515·05	85,819·62	....
		Sundry Claims	....	....	142·00	52·32	....	1,655·86	1,611·58	18,203·73	18,024·43	....
Majestic	....	Voided Leases	....	....	....	....	....	19·45	63·91	1,317·94	647·62	....
		Sundry Claims	....	....	....	....	....	42·88	154·58	1,926·58	959·78	....
Morelands	....	Sundry Claims	....	....	....	....	....	....	·13	308·75	81·84	....
Mount Monger	....	Voided Leases	....	....	....	....	....	....	2,771·39	1,437·85	1,256·10	....
		Sundry Claims	....	....	....	....	....	215·60	....	379·05	308·48	....
Randalls	....	Voided Leases	....	....	....	....	....	....	60·04	33,180·35	11,100·46	....

		Sundry Claims	....	....	....	....	....	20·70	9·79	4,842·56	1,216·07	....
Taurus	....	Voided Leases	....	....	....	....	....	2·06	3·70	1,765·10	909·84	....
		Sundry Claims	....	....	....	....	....	112·69	51·88	2,656·60	1,049·81	....
Hampton Plains	P.P.L. 308A, Loc. 41	Dawn of Hope (Trans Find)	....	....	....	....	....	....	2·87	1,145·75	330·33	....
		Voided Leases	....	....	....	....	....	....	....	1,098·42	876·22	....
		Sundry Claims	....	....	....	....	....	....	5·93	808·25	335·33	....
	From District Generally :—											
	Sundry Parcels treated at :—											
	Various Works		....	....	....	....	....	....	....	6,102·15	6,675·38	....
	Reported by Banks and Gold Dealers		·20	....	....	....	....	25,225·13	70·15	·01	28·44	....
		Total	**·20**	**2·20**	**204·50**	**59·06**	....	**27,405·42**	**16,036·77**	**187,992·33**	**132,362·31**	**12·92**

Coolgardie Goldfield.

COOLGARDIE DISTRICT.

Bonnievale	G.M.L. 6017	Hodges Hope	....	....	356·50	15·42	....	....	....	356·50	15·42	....
	5986	Jenny Wren	....	....	116·25	99·00	....	....	....	361·25	219·59	·29
	5622	Lucky Hit	....	....	18·25	54·01	....	....	3·28	1,146·35	676·78	....
	5890	Rayjax	....	....	56·25	79·98	....	....	....	614·50	1,048·94	3·61
	6007	Sabrina	....	....	14·50	6·61	....	....	....	24·25	20·27	....
		Voided Leases	....	....	....	....	....	....	212·48	362,696·87	196,412·90	19·86
		Sundry Claims	....	....	97·25	42·51	....	....	238·91	8,519·13	5,505·28	·87
Bulla Bulling	6003	Worked Out	....	....	11·25	6·22	....	....	....	135·75	146·21	....
		Voided Leases	....	....	....	....	....	....	....	1,410·56	968·52	....
		Sundry Claims	....	....	....	....	....	5·21	15·98	2,068·76	819·66	....
Burbanks	....	Voided Leases	....	....	....	....	....	14·90	376·98	420,591·86	306,446·31	521·06
		Sundry Claims	....	....	122·50	24·24	....	55·05	497·55	17,427·35	9,266·09	·93
Cave Rocks	....	Voided Leases	....	....	....	....	....	....	....	8,223·16	1,941·42	....
		Sundry Claims	....	....	173·50	16·87	....	....	50·00	4,710·65	1,108·14	....
Coolgardie	5935, etc.	Gold Mines of Kalgoorlie (Aust.) Ltd.	....	166·69	6,398·50	2,795·45	....	....	166·69	145,661·50	72,949·04	907·43
	5876	(Bayleys West)	....	....	....	....	....	....	....	6·25	2·22	....
	6000	Den Don	....	....	292·00	21·66	....	....	....	1,240·50	148·17	....
	6010	Emperor of Coolgardie	....	5·12	....	....	....	....	15·57	46·50	58·30	....
	5844	Jackpot	....	....	43·50	12·14	....	....	....	9,942·00	4,152·18	....
	5884	Lone Hand	....	....	....	....	....	....	19·85	499·00	84·85	....
		Voided Leases	....	....	....	....	....	1,301·71	5,282·28	1,111,875·44	450,779·25	4,820·20
		Sundry Claims	·32	....	1,445·50	231·65	....	219·79	2,802·92	82,142·44	29,002·76	·17
Eundynie	....	Voided Leases	....	....	....	....	....	3·70	16·09	31,772·98	16,531·34	1·75
		Sundry Claims	....	....	....	....	....	8·85	229·66	698·12	521·20	....
Gibraltar	5723	Lloyd George	....	....	....	....	....	....	....	763·00	176·78	....
		Voided Leases	....	....	....	....	....	....	33·97	38,762·63	20,114·27	....
		Sundry Claims	....	....	....	....	....	1·39	50·76	3,488·60	1,412·01	....
Gnarlbine	....	Voided Leases	....	....	....	....	....	....	13·95	2,731·75	1,341·60	....
		Sundry Claims	....	....	....	....	....	....	4·90	1,186·10	504·18	....

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 1963					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.*												
Hampton Plains	P.P.L. 489	C. L. Voumard	....	73·47	77·25	37·77	....	....	73·47	77·25	37·77	....
	448	T. R. Baker	....	....	690·75	49·61	....	....	....	690·75	49·61	....
	462	Bobby Dazzler	....	....	....	....	....	....	28·55	31·37	301·45	....
	419	Chatanooka	....	....	....	....	....	....	....	1,267·75	295·73	1·10
	335	D. & C. P. Clews	....	....	....	....	....	....	....	149·75	119·66	....
	338	Dry Hill	....	....	....	....	....	....	....	43·00	58·42	....
	465	G. Dugan & Party	....	....	....	....	....	....	....	53·75	17·54	....
	454	Golden Dollar	....	....	....	....	....	....	....	105·50	13·66	....
	319	Lady May	....	....	....	....	....	....	....	248·25	146·21	....
	319	(Lady May)	....	....	....	....	....	....	....	1,742·25	981·39	....
	334	Gold Mines of Kalgoorlie (Aust.) Ltd.	....	....	875·75	222·28	....	....	....	2,813·50	998·98	....
	468	Nichols & Hacket	....	....	....	....	....	....	....	24·25	5·30	....
	469	Cullen & Frank	....	....	....	....	....	....	6·46	3·75	2·34	....
	316, 330	Gold Mines of Kalgoorlie (Aust.) Ltd.	....	....	110·50	32·06	....	....	....	262,022·25	134,266·26	29,873·27
	316	(Surprise Gold Mine)	....	....	....	....	....	....	....	7,189·00	3,425·59	....
	330	(Barbara)	....	....	....	....	....	....	....	2,157·75	1,655·63	....
	471	A. J. Wells	....	....	....	....	....	....	....	45·00	1·40	....
	472	F. Clarke	....	....	....	....	....	....	....	30·75	4·02	....
	473	Austin & Hadlow	....	....	....	....	....	2·56	....	30·00	28·38	....
	475	F. J. Wallace	....	....	....	....	....	....	....	16·00	5·22	....
	478	A. E. Smith	....	....	....	....	....	....	....	22·25	57·73	....
	481	C. W. Avard	....	....	....	....	....	....	....	115·00	82·38	....
	482	T. R. Baker	....	....	277·75	29·19	....	....	....	1,094·75	161·50	·08
	486	H. Boucher	....	....	112·75	22·74	....	....	....	207·00	53·17	....
	487	F. C. Bray	....	....	....	....	....	....	....	35·00	2·78	....
		Cancelled Leases	....	....	....	....	....	....	451·32	13,950·84	11,118·69	....
		Sundry Claims and Leases	....	....	....	....	....	1·63	132·06	1,948·00	856·51	....
Higginsville	G.M.L. 5647	Fairplay Gold Mine	....	....	127·00	14·48	....	....	62·70	28,646·75	3,191·70	·02
	6002	Two Boys	....	....	251·00	53·63	....	....	....	794·25	245·21	·08
		Voided Leases	....	....	....	....	....	....	482·47	45,601·85	22,058·79	160·72
		Sundry Claims	....	....	57·00	5·91	....	....	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	....	....	232·00	25·73	....	....	....	232·00	25·73	....
		Voided Leases	....	....	....	....	....	....	11·09	106,660·81	26,931·68	....
		Sundry Claims	....	....	57·50	13·58	....	6·88	128·95	3,385·10	1,055·96	....
London Derby	....	Voided Leases	....	....	....	....	....	....	95·04	34,155·35	22,238·37	·35
		Sundry Claims	....	2·12	....	....	....	16·68	80·78	4,208·92	2,682·09	22·42

Mungari	....	Voided Leases	....	....	....	....	....	....	17·71	1,872·50	458·43	....
		Sundry Claims	....	....	....	....	....	1·77	153·24	2,953·44	761·56	....
Paris	5953, etc.	Paris Gold Mines Pty. Ltd.	....	....	13,733·00	4,289·43	5,817·72	....	....	42,516·00	12,614·14	12,190·68
	5873	(Paris West)	....	....	....	....	....	....	....	19·00	11·03	....
		Voided Leases	....	....	....	....	....	·88	4·30	15,497·00	8,625·37	79·19
		Sundry Claims	....	....	18·75	2·99	....	....	....	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	G.M.L. 5999	Little Nipper	....	305·15	6·50	70·45	....	....	1,101·44	39·50	353·14	....
		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	·42	....	19·00	2·69	....	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.	....	....	3,585·00	912·10	486·12	....	....	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....	....	....	....	314·14	....	....	....	771·01	*41,014·06	17·13
		Aust. Mach. and Investment Plant	....	....	....	....	....	....	....	....	*3,044·44	86·31
		T. A. James Plant	....	....	....	....	....	....	....	361·00	§373·02	....
		Various Works	....	....	....	....	....	7·75	....	4,014·61	29,780·07	223·06
	Reported by Banks and Gold Dealers	....	5·67	....	....	1·80	....	1,499·46	739·40	48·25	141·36	1·05
		Total	**6·41**	**552·55**	**29,377·25**	**9,506·34**	**6,303·84**	**17,036·59**	**19,181·03**	**2,989,094·60**	**1,533,138·49**	**49,417·99**

KUNANALLING DISTRICT.

Carbine	G.M.L. 1048S	Carbine	....	....	....	....	....	....	....	13,853·50	7,065·75	....
	33S, etc.	Carbine leases	....	....	....	....	....	....	687·98	51,991·86	39,862·25	....
		Voided leases	....	....	....	....	....	....	....	20,116·00	5,470·81	....
		Sundry claims	....	....	113·50	31·75	....	136·27	96·96	6,651·63	2,364·90	....
Chadwin	....	Voided leases	....	....	....	....	....	....	....	4,837·80	5,298·69	2·50
		Sundry claims	....	....	....	....	....	14·28	82·36	5,987·55	2,953·07	·25
Dunnsville	....	Voided leases	....	....	....	....	....	....	828·58	17,548·85	8,657·45	....
		Sundry claims	....	....	45·75	4·01	....	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	2,037·00	917·52	1·05
Kintore	....	Voided leases	....	....	....	....	....	18·70	169·33	56,822·89	40,044·61	677·88
		Sundry claims	....	....	38·75	11·67	....	111·91	102·70	4,908·28	2,589·61	....

Table I.—*Production of Gold and Silver from all sources, etc.*—continued.

COOLGARDIE GOLDFIELD—continued

KUNANALLING DISTRICT—*continued*

Mining Centre	Number of Lease	Registered Name of Company or Lease	Total for 1963 Alluvial	Total for 1963 Dollied and Specimens	Total for 1963 Ore treated	Total for 1963 Gold therefrom	Total for 1963 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.
Kunanalling	....	Voided leases	....	....	....	....	....	86·13	1,734·92	130,303·61	100,812·73	40·77
		Sundry claims	....	....	141·50	25·92	....	216·53	960·73	16,199·52	10,085·78	8·14
Kundana	....	Voided leases	....	....	....	....	....	....	....	465·00	68·12	....
		Sundry claims	....	....	....	....	....	....	....	475·25	60·38	....
	From District generally:—											
	Sundry Parcels treated at:—											
	Goldfields Aust. Development Plant		....	....	....	....	....	....	....	....	*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	....	....	**339·50**	**73·35**	....	**1,520·70**	**5,783·38**	**365,061·70**	**253,387·55**	**759·53**

Yilgarn Goldfield.

Mining Centre	Number of Lease	Registered Name of Company or Lease	Total for 1963 Alluvial	Total for 1963 Dollied and Specimens	Total for 1963 Ore treated	Total for 1963 Gold therefrom	Total for 1963 Silver	Total Production Alluvial	Total Production Dollied and Specimens	Total Production Ore treated	Total Production Gold therefrom	Total Production Silver
Blackbornes	....	Voided leases	....	....	....	....	....	....	....	1,282·50	341·37	....
		Sundry claims	....	....	....	....	....	....	....	392·50	81·15	....
Bullfinch	G.M.L. (3350), etc.	Great Western Consol. N.L. (Copperhead)	....	....	80,890·00	9,706·67	1,698·23	....	....	3,319,855·00	457,102·39	126,824·38
		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	....	....	29·50	42·44	5·59	8·47	45·49	7,593·89	4,156·71	14·09
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	·66	....	31·50	17·45	·58	3·16	90·95	2,873·95	2,052·04	4·39
Evanston	....	Voided leases	....	....	....	....	....	....	79·27	64,533·06	33,191·88	10·14
		Sundry claims	....	....	....	....	....	4·98	....	638·35	159·55	....
Forrestonia	4506	Margaret Ellen	....	....	30·00	12·14	....	....	....	84·00	21·79	·70
		Voided leases	....	....	....	....	....	....	....	1,185·00	298·15	....
		Sundry claims	....	·49	25·50	12·08	·51	....	·49	578·75	285·71	8·47
Golden Valley ..	4247	Lily of the Valley	....	....	....	....	....	....	....	709·00	177·73	....
	3266, etc.	Radio leases	....	....	1,092·00	1,096·15	181·22	....	2·70	44,870·80	65,314·40	1,693·16
		Voided leases	....	....	....	....	....	....	36·34	39,658·92	29,100·38	29·54
		Sundry claims	....	....	....	....	....	4·58	241·60	6,679·07	4,950·53	2·34

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Greenmount	....	Voided leases	....	....	....	....	....	45·99	21·62	125,905·64	31,667·08	961·19
		Sundry claims	....	....	....	....	....	·46	4·27	3,152·58	832·58	5·28
Holleton	4450	Brittania	....	....	....	....	....	....	....	2,200·00	1,726·15	....
		Voided leases	....	....	....	....	....	....	9·33	45,003·25	13,147·88	36·69
		Sundry claims	....	....	....	....	....	....	3·75	3,464·05	923·78	·20
Hopes Hill	4509	Hill View	....	....	35·00	2·01	·06	....	....	35·00	2·01	·06
		Voided leases	....	....	....	....	....	....	74·78	314,574·67	63,026·25	4,364·39
		Sundry claims	....	....	37·00	5·80	·24	21·12	95·75	4,708·27	1,463·61	1·20
Kennyville	3875	Victoria	....	....	28·00	10·82	·94	....	....	5,458·00	1,206·32	2·12
		Voided leases	....	....	....	....	....	....	18·76	55,876·63	21,625·66	·59
		Sundry claims	....	....	16·00	4·64	·31	....	5·06	8,720·50	2,346·84	·45
Koolyanobbing	....	Voided leases	....	....	....	....	....	....	·99	1,768·05	972·77	....
		Sundry claims	....	....	....	....	....	·26	17·33	724·85	339·23	....
Marvel Loch	G.M.L. 4499	Bohemia	....	....	....	....	....	....	....	44·00	18·31	·98
	4434	Cornwall	....	....	49·00	7·18	·37	....	....	17,769·00	2,464·95	527·91
	4039	Cromwell	....	....	....	....	....	....	....	995·50	159·91	....
	3942, etc.	Edwards Reward Leases	....	....	1,293·50	392·43	37·38	....	....	74,033·00	32,139·81	399·11
	3942	(Edwards Reward)	....	....	....	....	....	....	....	2,080·00	2,016·32	....
	3943	(Sunshine)	....	....	....	....	....	....	....	3,866·00	2,384·79	....
	4034	Firelight	....	....	....	....	....	....	2·68	6,653·75	940·03	....
	3724	Frances Firness	....	106·61	1,615·00	493·81	64·32	....	498·39	19,879·25	9,035·46	195·26
	(4375)	Great Western Consol. N.L.	....	....	189·00	23·05	4·08	....	....	317,269·00	64,020·54	13,088·69
	4435	I.X.L.	....	....	....	....	....	....	....	245·25	35·59	·62
	4230	May Queen	....	....	....	....	....	....	....	286·00	43·42	....
	3970	Mountain Queen	....	....	38·50	1·78	·12	....	....	1,328·00	472·74	1·87
	4384	Newry	....	....	....	....	....	....	....	6,061·75	714·72	97·34
	4419	Prince George	....	....	....	....	....	....	....	5,463·00	591·19	102·72
	4035	Undaunted	....	....	....	....	....	....	....	865·00	113·59	....
		Voided leases	....	....	....	....	....	....	1,546·04	885,649·83	212,844·84	2,761·93
		Sundry claims	....	....	50·00	14·77	1·00	11·35	809·31	38,437·59	13,883·41	84·46
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	....	1·69	8·50	5·73	·40	2·03	1·69	591·50	103·33	·40
	M.L. 4	Yellowdine Gold Dev. Pty. Ltd.	....	....	....	....	....	....	....	93·00	136·46	....
		Voided leases	....	....	....	....	....	....	....	306,531·65	158,527·11	
		Sundry claims	....	....	....	....	....	1,643·48	18·19	450·25	387·14	....
Mt. Rankin	G.M.L. 4462	Golden View	....	....	....	....	....	....	316·90	142·00	284·87	2·38
	4469	Lynette	....	....	37·00	7·96	·37	....	....	933·50	375·13	24·55
	4461	Marjorie Glen Reward	....	....	29·50	26·90	·76	....	191·46	3,210·55	4,047·72	4·85
		Voided leases	....	....	....	....	....	3·84	5·20	6,058·37	975·23	....
		Sundry claims	....	....	....	....	....	....	1·85	771·00	956·57	....
Parker's Range	4508	Buffalo	....	....	....	....	....	....	....	150·00	29·70	·42
	4504	Constance Una	....	....	54·50	68·91	4·67	....	....	113·50	138·51	9·52
		Voided leases	....	....	....	....	....	·42	270·76	64,082·85	32,812·23	27·43
		Sundry claims	....	....	4·50	1·42	·10	6·59	303·93	13,286·30	5,610·83	1·35

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 1963					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.										
Southern Cross	4424	Excelsior	....	....	50·50	6·34	·33	....	....	166·00	17·19	1·14
	4081	Fraser's Central	....	....	11·25	12·49	1·54	....	....	11·25	12·49	1·54
	4002, etc.	Great Western Consol. N.L. (Frasers)....	....	....	42,983·50	5,429·32	960·51	....	....	411,805·50	93,913·97	19,909·11
		Prior to transfer to present holders	....	....	....	....	....	....	....	13,720·50	1,876·00	1·26
	3444	(Three Boys)	....	....	....	....	....	....	....	4,180·00	727·75	....
	3934	(Three Boys North)	....	....	....	....	....	....	....	106·00	14·66	....
	3981	(Three Kings)	....	....	....	....	....	....	....	104·00	10·01	....
	3444	(Yellowdine Options N.L.)	....	....	....	....	....	....	....	8,074·25	2,000·29	....
	4510	Three Boys	....	....	·50	69·69	6·03	....	....	·50	69·69	6·03
		Voided leases	....	....	....	....	....	4·89	261·35	454,906·68	215,351·50	364·41
		Sundry claims	....	....	147·00	63·02	4·02	95·90	648·99	8,586·16	2,732·06	6·66
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 :											
		W. B. Ridge, Evanston Plant	....	....	....	....	....	....	....	....	*4,210·25	964·42
		Great Western Consol. N.L. (Frasers)	....	....	....	....	....	....	....	....	*1,357·18	85·92
		Great Western Consol. N.L. (Copperhead)	....	....	....	....	....	....	....	....	*5,770·90	458·63
		Kurrajong Battery	....	....	....	....	....	....	....	....	* 409·57	....
		Pilot Cyanide Plant	....	....	....	....	....	....	....	30·00	*3,753·59	....
		R. R. Robinson's Plant	....	....	....	....	....	....	....	....	*1,408·40	....
		Three Boys Cyanide Plant	....	....	....	*38·06	....	....	....	7·00	*4,039·08	19·78
		Harpers Battery	....	....	....	....	....	....	....	....	*479·51	96·24
		J. Cruickshank (L.T.T. 1504H)	....	....	36·00	5·79	·07	....	....	36·00	5·79	·07
		J. Cruickshank (L.T.T. 2/62)	....	....	....	....	....	....	....	35·00	12·21	·29
		Great Western Consol. (L.T.T. 2/61)	....	....	....	....	....	....	....	30·00	·30	·03
		Great Western Consol. (L.T.T. 1/61)	....	....	....	....	....	....	....	....	*204·38	39·42
		State Battery, Marvel Loch	....	....	....	*215·60	....	....	....	29·00	2,097·83	3·06
		Various Works	....	....	....	....	....	....	....	364·98	*99,526·93	120·01
	Reported Banks and Gold Dealers		....	....	....	....	....	325·11	81·41	·60	170·54	....
		Total	**·66**	**108·79**	**128,812·25**	**17,794·45**	**2,973·75**	**2,198·58**	**6,307·19**	**8,274,798·77**	**2,432,334·39**	**212,973·88**

Dundas 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
Beete	G.M.L. 1908	Beete	....	....	50·00	33·74	1·99	....	....	694·50	530·89	22·99
	1907	Eldridge's Find	....	....	258·75	168·65	7·12	....	....	1,176·50	947·34	42·19
		Sundry claims	....	....	....	....	....	....	....	386·50	376·41	....
Buldania	....	Voided leases	....	....	....	....	....	....	3·02	846·05	708·99	....
		Sundry claims	....	....	....	....	....	....	39·25	1,324·27	861·36	·72

Dundas	....	Voided leases	....	....	....	....	....	1·88	28·02	6,241·98	2,560·53	155·02
		Sundry claims	....	....	....	....	....	·76	413·85	2,275·25	1,165·27	20·08
Norseman	1935	Bull Ant	....	....	105·00	2·96	·15	....	....	263·25	6·40	·22
	1288, etc.	Central Norseman Gold Coporation N.L.	....	....	189,248·00	102,701·75	52,056·42	....	....	3,596,335·20	1,657,607·78	1,079,023·36
		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	916,801·92	601,844·69	39,001·74
		Sundry claims	....	22·12	180·00	20·79	2·95	1,052·09	3,513·58	49,610·95	22,591·88	223·17
Peninsula	....	Voided leases	....	....	....	....	....	....	24·29	9,603·39	6,102·61	12·20
		Sundry claims	....	....	....	....	....	....	....	217·25	119·32	·97
From Goldfield generally :—												
Sundry Parcels treated at :—												
M. E. Haurigan (L.T.T. 1447H)			....	....	....	....	....	....	....	87·00	5·36	....
J. H. Smith (L.T.T. 1479H)			....	....	....	....	....	....	....	162·00	8·24	·56
State Battery, Norseman			....	....	....	....	....	....	....	427·89	*25,358·99	1,051·53
Various Works			....	....	....	....	....	....	54·52	780·89	*15,110·71	2,588·35
Reported by Banks and Gold Dealers			1·01	....	....	....	....	1,182·78	49·59	47·50	21·37	·70
		Total	**1·01**	**22·12**	**189,841·75**	**102,927·89**	**52,068·63**	**2,251·78**	**16,390·59**	**5,641,858·12**	**2,628,739·32**	**1,496,840·19**

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. 35, etc.	Ravensthorpe Copper Mines N.L.	....	....	....	§2,541·86	6,910·01	....	....	....	§12,072·02	36,449·87
	M.L. 421	Big Surprise	....	....	....	....	....	....	....	6·46	3·03	‡116·48
		Voided leases	....	....	....	....	....	....	141·80	24,723·55	26,070·94	4,384·07
		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 :—												
F. E. Daw's Plant (T.A. 11)			....	....	....	....	....	....	....	....	*128·45	....
Various Works			....	....	....	....	....	....	....	27·00	*4,118·73	515·43
Reported by Banks and Gold Dealers			....	....	....	....	....	164·69	14·61	....	8·47	....
		Total	....	....	....	**2,541·86**	**6,910·01**	**607·11**	**823·32**	**130,659·24**	**116,146·65**	**52,592·95**

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 1963					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.
		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	....	....	17·00	32·76	....	....	·98	389·75	246·73	....
Donnybrook	....	Voided leases	....	....	....	....	....	23·24	....	1,613·30	816·23	....
		Sundry claims	....	....	....	....	....	44·01	43·03	119·50	15·71	15·18
Lake Grace	G.M.L. 106H	Griffins Find	....	....	....	....	....	....	....	294·00	154·39	....
		Sundry claims	....	....	....	....	....	....	....	27·75	17·91	....
Ongerup	103H	Hornblende	....	....	....	....	....	....	....	24·50	2·85	....
		Sundry claims	....	....	....	....	....	....	1·58	·33	1·74	....
	From Mineral Field generally :—	Miscellaneous voided leases and sundry claims	....	....	....	....	....	245·83	3·07	1,472·10	353·19	....
		Total	....	....	**17·00**	**32·76**	....	**313·08**	**48·66**	**4,652·08**	**2,315·13**	**15·18**
		State Generally.										
	Sundry Parcels treated at :—											
		Various Works	....	....	....	....	....	....	....	27·00	9,009·75	31,521·73
		Reported by Banks and Gold Dealers	·64	·50	....	·56	....	1,189·88	1,110·71	....	967·53	1,140·93
		Total	**·64**	**·50**	....	**·56**	....	**1,189·88**	**1,110·71**	**27·00**	**9,977·28**	**32,662·66**

TABLE II

Production of Gold and Silver from all Sources, showing in fine ounces the output, as reported to the Mines Department during the year 1963.

Goldfield	District	District						Goldfield					
		Alluvial	Dollied and Specimens	Ore Treated	Gold Therefrom	Total Gold Therefrom	Silver	Alluvial	Dollied and Specimens	Ore Treated	Gold Therefrom	Total Gold Therefrom	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	....	....	....	....	....	....	....	52·20	81·51	120·00	26·13	159·84	....
West Kimberley	....	....	....	....	....	....	....	....	....	....	....	....	....
Pilbara	Marble Bar	48·84	·20	1,235·25	1,487·31	1,536·35	78·95	87·75	·20	1,933·50	1,676·40	1,764·35	80·19
	Nullagine	38·91	....	698·25	189·09	228·00	1·24						
West Pilbara	....	....	....	....	....	....	....	....	....	....	....	....	....
Ashburton	....	....	....	....	....	....	....	....	....	....	....	....	....
Gascoyne	....	....	....	....	....	....	....	....	1·77	124·25	239·71	241·48	9·68
Peak Hill	....	....	....	....	....	....	....	....	....	817·00	87·46	87·46	3·56
East Murchison	Lawlers	....	....	273·00	142·45	142·45	7·17	....	....	545·50	277·51	277·51	16·91
	Wiluna	....	....	35·00	63·88	63·88	6·84						
	Black Range	....	....	237·50	71·18	71·18	2·90						
Murchison	Cue	13·54	....	788·25	215·65	229·19	234·72	19·38	23·31	171,082·50	83,657·98	83,700·67	6,560·69
	Meekatharra	5·56	....	2,978·25	490·74	496·30	24·29						
	Day Dawn	....	....	60·00	6·86	6·86	·22						
	Mt. Magnet	·28	23·31	167,256·00	82,944·73	82,968·32	6,301·46						
Yalgoo	....	....	....	....	....	....	....	·36	....	161·50	101·12	101·48	6·24
Mt. Margaret	Mount Morganus	9·89	....	139·00	87·28	97·17	6·71	11·89	....	162,533·75	31,969·66	31,981·55	2,899·26
	Mount Malcolm	2·00	....	162,394·75	31,882·38	31,884·38	2,892·55						
	Mt. Margaret	....	....	....	....	....	....						
North Coolgardie	Menzies	5·62	3·61	31,207·65	15,260·34	15,209·57	575·06	5·62	3·61	34,928·15	18,347·06	18,356·29	866·36
	Ularring	....	....	531·25	654·16	654·16	38·04						
	Niagara	....	....	1,100·25	401·66	401·66	8·47						
	Yerilla	....	....	2,089·00	2,030·90	2,030·90	244·79						
Broad Arrow	....	....	....	....	....	....	....	6·59	....	8,417·25	1,278·55	1,285·14	·24
North-East Coolgardie	Kanowna	2·51	....	290·00	71·50	74·01	·10	2·51	....	610·25	229·13	231·64	·10
	Kurnalpi	....	....	320·25	157·63	157·63	....						
East Coolgardie	East Coolgardie	6·93	39·98	2,040,300·50	530,994·11	531,041·02	142,064·80	7·13	42·18	2,040,505·00	531,053·17	531,102·48	142,064·80
	Bulong	·20	2·20	204·50	59·06	61·46	....						
Coolgardie	Coolgardie	6·41	552·55	29,377·25	9,506·34	10,065·30	6,303·84	6·41	552·55	29,716·75	9,579·69	10,138·65	6,303·84
	Kunanalling	....	....	339·50	73·35	73·35	....						
Yilgarn	....	....	....	....	....	....	....	·66	108·79	128,812·25	17,794·45	17,903·90	2,973·75
Dundas	....	....	....	....	....	....	....	1·01	22·12	189,841·75	102,927·89	102,951·02	52,068·63
Phillips River	....	....	....	....	....	....	....	....	....	....	541·86	2,541·86	6,910·01
South-West Mineral Field	....	....	....	....	....	....	....	....	....	17·00	32·76	32·76	....
Northampton Mineral Field	....	....	....	....	....	....	....	....	....	....	....	....	....
State Generally	....	....	....	....	....	....	....	·64	·50	....	·56	1·70	....
Outside Proclaimed Goldfield	....	....	....	....	....	....	....	....	....	....	....	....	....
Total	....	....	....	....	....	....	....	**202·15**	**836·54**	**2,770,166·40**	**801,821·09**	**802.859·78**	**220,764·26**

TABLE III

Return showing total production reported to the Mines Department, and respective Districts and Goldfields from whence derived, to 31st December, 1963.

Goldfield	District	District						Goldfield					
		Alluvial	Dollied and Specimens	Ore Treated	Gold Therefrom	Total Gold Therefrom	Silver	Alluvial	Dollied and Specimens	Ore Treated	Gold Therefrom	Total Gold Therefrom	Silver
		Fine ozs.	Fine ozs.	Tons (2,240 lb.)	Fine ozs.	Fine ozs.	Fine ozs.	Fine ozs.	Fine ozs.	Tons (2,240 lb.)	Fine ozs.	Fine ozs.	Fine ozs.
Kimberley	....	....	....	....	....	....	....	9,079·68	3,016·35	22,871·90	17,266·45	29,362·48	128·76
West Kimberley	....	....	....	....	....	....	....	1·30	24·68	1·00	2·49	28·47	13,575·29
West Pilbara	....	....	....	....	....	....	....	6,339·37	374·74	24,900·96	24,317·02	31,031·13	1,910·66
Pilbara	Marble Bar	15,314·86	4,569·14	341,601·72	330,545·29	350,429·29	32,902·64	25,795·38	7,476·19	491,406·14	465,974·31	499,245·88	33,982·93
	Nullagine	10,480·52	2,907·05	149,804·42	135,429·02	148,816·59	1,080·29						
Ashburton	....	....	....	....	....	....	....	9,267·37	482·46	6,807·10	2,913·43	12,663·26	41,971·38
Gascoyne	....	....	....	....	....	....	....	698·13	120·37	789·75	1,613·49	2,431·99	46·22
Peak Hill	....	....	....	....	....	....	....	3,387·79	5,300·88	781,766·73	322,689·99	331,378·66	3,789·83
East Murchison	Lawlers	7,103·38	2,343·19	2,013,929·17	823,532·82	832,979·39	27,202·85	9,010·40	22,207·27	12,618,856·33	3,650,945·59	3,682,163·26	60,234·24
	Wiluna	236·48	1,254·11	8,873,639·19	1,872,262·62	1,873,753·21	10,307·23						
	Black Range	1,670·54	18,609·97	1,731,287·97	955,150·15	975,430·66	22,724·16						
Murchison	Cue	5,121·73	9,104·99	6,813,672·56	1,402,082·41	1,416,309·13	274,386·08	25,645·92	59,174·57	14,343,126·62	5,729,514·11	5,814,334·60	499,136·97
	Meekatharra	14,643·79	18,260·03	2,311,480·56	1,308,729·70	1,341,633·52	5,197·20						
	Day Dawn	3,245·17	11,341·80	2,037,357·13	1,375,560·86	1,390,147·83	169,436·51						
	Mt. Magnet	2,635·23	20,467·75	3,180,616·37	1,643,141·14	1,666,244·12	50,117·18						
Yalgoo	....	....	....	....	....	....	....	1,808·38	3,223·19	443,349·58	264,036·39	269,067·96	1,522·41
Mt. Margaret	Mt. Morgans	3,571·23	9,398·51	1,217,696·31	717,905·54	730,875·28	5,828·32	11,776·64	35,421·85	11,495,355·52	4,960,525·00	5,007,723·49	262,701·39
	Mt. Malcolm	4,061·87	16,668·99	7,749,485·97	3,068,575·90	3,089,306·76	190,682·37						
	Mt. Margaret	4,143·54	9,354·35	2,528,173·24	1,174,043·56	1,187,541·45	66,190·70						
North Coolgardie	Menzies	1,693·32	7,018·53	1,858,566·33	1,393,042·05	1,401,753·90	32,740·66	4,853·11	19,873·53	3,631,497·58	2,542,879·26	2,567,605·90	65,645·94
	Ularring	129·52	7,216·11	534,411·20	444,456·65	451,802·25	22,024·84						
	Niagara	1,718·36	1,821·77	943,981·27	528,408·94	531,949·07	5,713·32						
	Yerilla	1,311·91	3,817·12	294,538·78	176,971·62	182,100·65	5,167·12						
Broad Arrow	....	....	....	....	....	....	....	21,988·45	27,995·95	1,371,960·26	743,856·60	793,841·00	5,429·59
North-East Coolgardie	Kanowna	106,538·83	13,526·67	1,009,633·31	627,293·48	747,358·98	3,044·65	119,375·47	21,825·58	1,023,736·88	646,301·59	787,502·64	3,057·36
	Kurnalpi	12,836·64	8,298·91	14,103·57	19,008·11	40,143·66	12·71						
East Coolgardie	East Coolgardie	33,719·69	41,186·82	83,555,641·60	35,504,587·96	35,579,494·47	5,584,639·69	61,125·11	57,223·59	83,743,633·93	35,636,950·27	35,755,298·97	5,584,652·61
	Bulong	27,405·42	16,036·77	187,992·33	132,362·31	175,804·50	12·92						
Coolgardie	Coolgardie	17,306·59	19,181·03	2,989,094·60	1,533,138·49	1,569,356·11	49,417·99	18,557·29	24,964·41	3,354,156·30	1,786,526·04	1,830,047·74	50,177·52
	Kunanalling	1,520·70	5,783·38	365,061·70	253,387·55	260,691·63	759·53						
Yilgarn	....	....	....	....	....	....	....	2,198·58	6,307·19	8,274,798·77	2,432,334·39	2,440,840·16	212,973·88
Dundas	....	....	....	....	....	....	....	2,251·78	16,390·59	5,641,858·12	2,628,739·32	2,647,381·69	1,496,840·19
Phillips River	....	....	....	....	....	....	....	607·11	823·32	130,659·24	116,146·65	117,577·08	52,592·95
South-West Mineral Field	....	....	....	....	....	....	....	313·08	48·66	4,652·08	2,315·13	2,676·87	15·18
Northampton Mineral Field	....	....	....	....	....	....	....	....	....	....	....	....	5,185·58
State Generally	....	....	....	....	....	....	....	1,189·88	1,110·71	27·00	9,977·28	12,277·87	32,662·66
Outside Proclaimed	....	....	....	....	....	....	....	....	....	....	....	....	....
Total	....	....	....	....	....	....	....	**335,270·22**	**313,386·08**	**147406211·79**	**61,985,824·80**	**62,634,481·10**	**8,428,233·54**

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
Total	11,591,169·57	52,757,524·91	64,166,694·48	483,332,430

	1962	1963
	£A	£A
Estimated Mint value of above production	466,928,519	479,431,826
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	1,296,623	1,311,002
Estimated Total	£A470,814,744	£A483,332,430
Bonus paid by Commonwealth Government under Commonwealth Bounty Act, 1930	161,448	161,448
Subsidy paid by Commonwealth Government under Gold Mining Industry Assistance Act, 1954, from 1955	4,251,043	4,921,256
Gross estimated value of gold won	£A475,272,235	£A488,415,134

TABLE V.

Quantity and Value of Minerals, other than Gold, Reported during the year 1963

Number of Lease, Claim or Area	Goldfield or Mineral Field	Registered Name of Producer	Quantity	Metallic Content	Value
		ASBESTOS (Chrysotile)			
			Long Tons		£A
M.C. 98L, etc.	Pilbara	Stubbs, S. H.	10·13	....	783·00 (*b*)
		ASBESTOS (Crocidolite)			
M.C. 53, etc.	West Pilbara	Australian Blue Asbestos Ltd.	11,094·57	....	1,202,002·01 (*b*)
		BENTONITE (See Clays)			
		BERYL (*f*) (*g*)			
				BeO Units	
M.C. 106	Pilbara	Hasleby, H. M. and H. B.	·61	6·74	72·15
M.C. 116	Pilbara	Tabba Tabba Mining Syndicate	1·94	19·23	243·90
Crown Lands	Pilbara	Sundry Persons	1·69	18·46	174·55
M.C. 241, etc.	West Pilbara	Nomads Pty. Ltd.	7·06	79·48	1,006·30
Crown Lands	West Pilbara	Sundry Persons	1·15	8·05	88·55
Crown Lands	Gascoyne	Sundry Persons	11·07	125·33	1,780·45
P.A. 3716	Murchison	Spencer, J. P.	1·23	12·92	126·65
M.C. 38	Yalgoo	Fogarty, M. & Party	1·32	15·60	169·55
P.A. 2605	Yalgoo	Clinch, E. M.	2·16	24·80	268·00
P.A. 2621	Yalgoo	Fogarty, C. A.	1·19	14·47	144·65
P.A. 2623	Yalgoo	McIntosh, A.	·27	2·93	26·40
M.C. 34	Yalgoo	Palmer, L.	16·29	183·75	2,228·90
M.C. 35	Yalgoo	Meka Mining Syndicate	18·96	221·51	2,663·35
P.A. 2580	Yalgoo	Phillips, E. R.	4·50	50·64	623·25
P.A. 2589	Yalgoo	Sipos, A.	·43	5·13	62·30
P.A. 2610	Yalgoo	Corney, R.	9·25	104·87	1,134·70
M.C. 98, etc.	Phillips River	Frayne, W. L.	2·91	29·63	288·80
			82·03	923·54	(*b*)11,102·45
		BUILDING STONE (Sandstone—Donnybrook)			
M.C. 906H	South-West	Wilson Gray & Co. Pty. Ltd.	83·00	....	(*c*)1,743·00
		BUILDING STONE (Spongolite)			
Q.A. 1	Phillips River	Ravensthorpe Freestone Quarries	394·00	....	(*c*)1,874·00
		BUILDING STONE (Granite—Facing Stone)			
M.C. 719H	South-West	Crawford Quarries Pty. Ltd.	82·00	....	(*c*)2,160·00
		CLAYS (Bentonite)			
M.C. 282H, etc.	South-West	Collins, A. C.	609·00	....	1,522·50
M.C. 437H, etc.	South-West	Noonan, E. J.	588·00	....	2,352·00
			1,197·00	....	(*a*)3,874·00
		CLAYS (Cement Clay)			
Private Property	South-West	Bell Bros. Pty. Ltd.	10,804·00	....	5,807·15
M.C. 492H, etc.	South-West	Cockburn Cement Pty. Ltd.	6,870·00	....	8,588·00
Private Property	South-West	Swan Portland Cement Ltd.	1,098·00	....	713·70
			18,772·00	....	(*c*)15,108·85
		CLAYS (Fireclay)			
M.C. 522H, etc.	South-West	Bridge, J. S. & T. D.	11,123·50	....	15,665·60
M.C. 304H, etc.	South-West	Clackline Refractories Ltd.	3,965·00	....	3,965·00
Private Property	South-West	Darling Range Firebrick Co. Pty. Ltd.	336·00	....	319·20
M.C. 685H	South-West	Kargotich Bros.	2,700·00	....	2,700·00
M.C. 732H	South-West	Midland Brick Co. Pty. Ltd.	6,877·00	....	3,438·50
			25,001·50	....	(*c*)26,088·30
		CLAYS (Kaolin)			
M.C. 247H, etc.	South-West	Linton, J. B.	125·54	....	(*c*)285·00
		CLAYS (White Clay—Ball Clay)			
M.C. 19E	East Coolgardie	Gardner, J. A.	75·00	....	225·00
M.C. 109H	South-West	H. L. Brisbane & Wunderlich Ltd.	719·00	....	2,876·00
			794·00	....	(*c*)3,101·00

TABLE V.—*Quantity and Value of Minerals, other than Gold, Reported during the Year* 1963—*continued*

Number of Lease, Claim or Area	Goldfield or Mineral Field	Registered Name of Producer	Quantity	Metallic Content	Value
		CLAYS (Brick, Pipe and Tile Clay)*			
M.C. 789H	South-West	Peters, O. V. & M. E.	7,011·00	....	5,750·00
Private Property	South-West	Stoneware Pipes & Tiles Pty. Ltd.	4,977·00	....	4,977·00
Private Property	South-West	Stoneware Pipes & Tiles Pty. Ltd.	4,718·00	....	4,718·00
Private Property	South-West	Stoneware Pipes & Tiles Pty. Ltd.	2,994·00	....	4,041·90
Private Property	South-West	Stoneware Pipes & Tiles	5,433·00	....	5,433·00
Private Property	South-West	Stoneware Pipes & Tiles Pty. Ltd.	2,844·00	....	2,844·00
Private Property	South-West	Swaby, F. W.	28,630·00	....	35,787·50
			56,607·00	....	(c)63,551·40

* Incomplete : Figures relate only to production from holdings under the Mining Act.

Number of Lease, Claim or Area	Goldfield or Mineral Field	Registered Name of Producer	Quantity	Metallic Content	Value
		COAL			
M.L 448, etc.	Collie	Griffin Coal Mining Co. Ltd.	534,129·30	....	995,929·50
M.L. 437, etc.	Collie	Western Collieries Ltd.	368,365·60	....	989,130·20
			902,494·90	....	1,985,059·70 (e)
		COPPER ORE AND CONCENTRATES (f) (g)			
M.C. 35, etc.	Phillips River	Ravensthorpe Copper Mines N.L.	5,860·02	Copper Units 135,628·00	290,120·10 (b)

Gold and Silver Content transferred to respective Items

Number of Lease, Claim or Area	Goldfield or Mineral Field	Registered Name of Producer	Quantity	Metallic Content	Value
		COPPER (Metallic By-product) (f) (g) (i)			
G.M.L. 5873, etc.	Coolgardie	Paris Gold Mines Pty. Ltd.	*	Copper Tons (g)76·98	(b)13,917·70

* From 405·73 tons Gold/Copper Concentrates exported.
Gold and Silver Content transferred to respective Items.

Number of Lease, Claim or Area	Goldfield or Mineral Field	Registered Name of Producer	Long Tons	Average Assay Cu. %	£A
		CUPREOUS ORE AND CONCENTRATES (Fertiliser)			
P.A. 2680	Pilbara	Matheson, J.	16·06	9·52	250·00
P.A. 2687	Pilbara	Burgess, C.	3·65	6·25	23·95
M.C. 633	Pilbara	Ward, H.	10·27	8·77	146·35
G.M.L. 314L	Pilbara	Copper Hills Copper Mine	81·00	13·25	3,480·00
M.C. 377L	Pilbara	Henderson, J. R. & C. B.	122·02	14·72	4,822·65
Crown Lands	Pilbara	Sundry Persons	1·00	13·00	30·25
Loc. 7	West Pilbara	Depuch Shipping & Mining Co. Pty. Ltd.	489·60	28·75	51,019·05
P.A. 294	West Pilbara	Norton, E. and Blackwell, V.	3·18	19·90	209·50
M.C. 240	West Pilbara	Cawse, L. W.	12·86	12·70	359·35
P.A. 296	West Pilbara	Komarek, F. & Quarmby, F.	2·76	10·30	53·50
M.L. 262	West Pilbara	Lee, T.	19·87	5·20	40·00
P.A. 339	Ashburton	Cumming, C. C.	1·76	23·82	133·50
M.C. 22, etc.	Ashburton	Ashburton Mining Co. Pty. Ltd.	82·37	19·14	5,913·80
M.L. 168	Ashburton	Rose, W. & Party	14·87	23·97	1,142·65
M.C. 54	Ashburton	Camp, F. J. & Party	2·71	14·60	88·75
Crown Lands	Ashburton	Sundry Persons	4·00	12·50	98·70
P.A. 62	Gascoyne	Hester, M. P.	5·71	18·60	277·60
P.A. 1553	East Murchison	Howarth, C. A.	13·61	8·79	223·55
P.A. 1586	East Murchison	Jones, L. S. D.	7·81	6·40	52·50
P.A. 900P	Peak Hill	Motter, Z. E.	285·03	7·40	3,382·75
M.C. 63P	Peak Hill	Parkinson, L. T.	167·03	13·74	7,791·30
M.C. 65P	Peak Hill	Lee, R.	105·62	11·20	3,814·20
M.L. 68P	Peak Hill	Thaduna Copper Mining Co. Pty. Ltd.	1,350·30	10·70	36,570·00
M.C. 39	Yalgoo	O'Callaghan & Howlett	106·71	9·04	2,128·75
M.C. 6F	Mt. Margaret	Alac, M.	98·48	11·69	2,632·05
P.A. 1672F	Mt. Margaret	Cable, J. L.	4·00	7·60	36·45
M.C. 36	Coolgardie	Horan, T. J.	6·03	16·30	280·10
P.A. 854	Phillips River	Weigner, W. & Party	3·80	15·60	221·75
M.L. 410	Phillips River	Kuzmins, W.	18·00	10·60	725·60
M.C. 160	Phillips River	Kuzmins, W.	24·00	12·60	1,134·20
M.C. 41	Phillips River	Kuzmins, W.	26·05	12·22	1,200·15
M.C. 35, etc.	Phillips River	Ravensthorpe Copper Mines N.L.	54·60	12·82	2,264·65
M.C. 151	Phillips River	Arbus, M.	5·00	6·80	60·00
P.A. 853	Phillips River	Hansen, J. E.	1·00	8·00	14·50
P.A. 276	Northampton	Cotic, A. C. and Griffiths, C. G.	7·19	12·97	223·70
Temp. Res. 2104H	Outside Proclaimed	United Aborigines Mission	76·80	22·32	5,354·05
			3,234·75	14·10	136,199·85 (a) (b)
		FELSPAR			
M.L. 80, etc.	Coolgardie	Australian Glass Manufacturers Co. Pty. Ltd.	992·00	....	(a)6,985·40

TABLE V.—*Quantity and Value of Minerals, other than Gold, Reported during the Year 1963—continued*

Number of Lease, Claim or Area	Goldfield or Mineral Field	Registered Name of Producer	Quantity	Metallic Content	Value
		GLASS SAND			
M.C. 417H, etc.	South-West	Australian Glass Manufacturers Co. Pty. Ltd.	8,366·09	....	5,439·05
M.C. 285H, etc.	South-West	Leach, R. J.	1,111·00	....	1,666·50
M.C. 161H, etc.	South-West	Leach, L. J.	449·00	....	449·00
			9,926·09	....	(c)7,554·55
		GYPSUM			
M.C. 30, etc.	Yilgarn	Ajax Plaster Co. Pty. Ltd.	8,548·00	....	7,034·00
M.C. 51, etc.	Yilgarn	H. B. Brady Co. Pty. Ltd.	7,970·00	....	9,963·00
M.C. 9, etc.	Yilgarn	West Australian Plaster Mills Pty.	11,844·00	....	9,587·00
M.C. 12, etc.	Dundas	McDonald and Whitfield	481·00	....	240·50
M.C. 25, etc.	Dundas	Garrick Agnew Pty. Ltd.	15,233·53	....	48,928·00
M.C. 881H	South-West	Dooka Gypsum Co.	27·00	....	135·00
M.C. 485H, etc.	South-West	Swan Portland Cement Ltd.	2,844·00	....	2,277·00
M.C. 612H, etc.	South-West	Hewitt, B.	3,704·75	....	4,678·65
Private Property	South-West	Dooka Gypsum Co.	156·00	....	624·00
			50,808·28	....	82,467·15 (a) (b)

Includes 15,233·53 tons for Export and 156·00 tons for Agricultural Purposes.

Plaster of Paris reported as manufactured during the year being 19,994·00 tons from 28,257·05 tons of Gypsum by five Companies.

Gypsum used in the manufacture of Cement = 8,691·00 tons.

		IRON ORE (For Pig)	Long Tons	Pig Iron Recovered Tons	£A
Temp Res. 1258H	Yilgarn	Charcoal Iron & Steel Industry	73,384·00	46,038·00	1,036,074·00 (c) (d)

Average Assay of Ore used = 61·60 Fe %

		IRON ORE (For Export)		Average Assay Fe %	
M.L. 10, etc.	West Kimberley	Australian Iron & Steel Ltd.	1,277,613·00	63·00	1,266,967·00 (b)
		LEAD ORE AND CONCENTRATES (f) (g)		Lead Content Tons	
M.L. 234	Northampton	Bridson, T. A.	184·93	135·87	(b)6,535·20
		LIMESTONE*			
M.C. 727H	South-West	Perron Bros. Pty. Ltd.	3,543·00	....	581·00
M.C. 723H	South-West	Plozza, C. W. & W. A.	60·00	....	60·00
M.C. 432H	South-West	Anticich, J.	287·20	....	287·20
M.C. 684H	South-West	Cooper, B. D.	1,181·00	....	1,476·25
M.C. 692H, etc.	South-West	Franconi, D. & S.	13,511·45	....	19,302·00
M.C. 532H	South-West	Gibbs, C. E. & A. J.	2,614·00	....	3,267·50
M.C. 575H, etc.	South-West	Susac, F. & Y.	4,380·00	....	5,475·00
M.C. 684H, etc.	South-West	Bell Bros. Pty. Ltd.	1,958·00	....	2,447·50
M.C. 50	Dundas	Esperance Lime Supply	360·98	....	721·95
			27,895·63	....	(c)33,618·40

* Incomplete: Figures relate only to production reported from holdings under the Mining Act.

		LITHIUM ORES (Petalite) (f) (g)		Li20 Units	
M.L. 80, etc.	Coolgardie	Australian Glass Manufacturers Co. Pty. Ltd.	390·02	1,642·24	3,708·90 (a) (b)
		LITHIUM ORES (Spodumene) (f) (g)		Li20 Units	
M.C. 23	Phillips River	Frayne, W. L.	22·00	132·00	(c)270·00
		MAGNESITE (f)			
M.C. 76H, etc.	Phillips River	Basic Materials Co. Pty. Ltd.	6,472·38	....	44,077·95
M.C. 60	Yilgarn	Read, J. E., Neil, L. R. & Fletcher, R. F.	22·15	....	88·60
			6,494·53	....	44,166·55 (a) (b)

TABLE V.—*Quantity and Value of Minerals, other than Gold, Reported during the Year 1963—continued*

Number of Lease, Claim or Area	Goldfield or Mineral Field	Registered Name of Producer	Quantity	Metallic Content	Value
		MANGANESE (Metallurgical Grade) (*f*)			
			Long Tons	Average Assay Mn %	£A
M.C. 268, etc.	Pilbara	Mt. Sydney Manganese Pty. Ltd.	22,503·96	50·95	315,329·85
M.C. 244L, etc.	Pilbara	Westralian Ores Pty. Ltd.	10,652·00	51·66	117,777·00
M.C. 24P, etc.	Peak Hill	Westralian Ores Pty. Ltd.	5,214·00	43·74	66.652·00
			38,369·96	50·17	499,758·85 (*b*)
		MANGANESE (Battery Grade)			
				Average Assay MnO2 %	
M.L. 61P	Peak Hill	Westralian Ores Pty. Ltd.	442·00	70·00	(*a*)8,840·00
		MANGANESE (Low Grade)			
				Average Assay Mn %	
M.C. 24P, etc.	Peak Hill	Westralian Ores Pty. Ltd.	545·00	Not Known	(*a*)4,396·20
		MINERAL BEACH SANDS (Ilmenite) (*f*)			
				Average Assay TiO2 %	
D.C. 56H, etc.	South-West	Cable (1956) Ltd.	6,783·31	55·14	See Footnote
D.C. 13H, etc.	South-West	Ilmenite Pty. Ltd.	34,732·50	54·59	
M.C. 619H, etc.	South-West	Westralian Oil Ltd.	33,703·00	58·83	
M.C. 516H, etc.	South-West	Western Titanium N.L.	61,661·12	55·09	
			136,879·93	55·89	(*b*)682,067·30

FOOTNOTE: Current values for separate Companies not available for publication.

Number of Lease, Claim or Area	Goldfield or Mineral Field	Registered Name of Producer	Quantity	Metallic Content	Value
		MINERAL BEACH SANDS (Monazite) (*f*) (*g*)			
				ThO2 Units	
M.C. 619H, etc.	South-West	Westralian Oil Ltd.	747·00	5,021·95	32,046·75
M.C. 516H, etc.	South-West	Western Titanium N.L.	301·81	2,091·67	11,292·00
			1,048·81	7,113·62	(*b*)43,338·75
		MINERAL BEACH SANDS (Rutile) (*f*) (*g*)			
				TiO2 Units	
M.C. 516H, etc.	South-West	Western Titanium N.L.	606·00	581·56	(*b*)18,034·50
		MINERAL BEACH SANDS (Leucoxene) (*f*) (*g*)			
				TiO2 Tons	
M.C. 619H, etc.	South-West	Westralian Oil Ltd.	65·00	49·96	1,280·00
M.C. 516H, etc.	South-West	Western Titanium N.L.	395·00	342·86	4,703·35
			460·00	392·82	(*b*)5,983·35
		MINERAL BEACH SANDS (Zircon) (*f*) (*g*)			
				ZrO2 Tons	
M.C. 619H, etc.	South-West	Westralian Oil Ltd.	230·00	150·42	2,175·00
M.C. 516H, etc.	South-West	Western Titanium N.L.	4,342·85	2,862·49	43,626·60
			4,572·85	3,012·91	(*b*)45,801·60
		OCHRE (Red)			
M.C. 30	Murchison	Universal Milling Co. Pty. Ltd.	212·80	....	(*a*)1,278·00
		PETALITE (See Lithium Ores)			
		PHOSPHATIC GUANO			
M.C. 714H	South-West	Ward, R. J.	16·00	....	(*c*)160·00
		PYRITES ORE & CONCENTRATES (For Sulphur)			
				Sulphur Content Tons	
G.M.L. 5345E, etc.	East Coolgardie	Gold Mines of Kalgoorlie (Aust.) Ltd.	23,579·31	8,516·72	106,404·90
G.M.L. 1460, etc.	Dundas	Norseman Gold Mines N.L.	34,893·00	16,708·73	278,470·00
			58,472·31	25,225·45	(*a*)384,874·90

TABLE V.—*Quantity and Value of Minerals, other than Gold, Reported during the Year 1963—continued*

Number of Lease, Claim or Area	Goldfield or Mineral Field	Registered Name of Producer	Quantity	Metallic Content	Value
		QUARTZ GRIT	Long Tons		£A
Q.A. 2	Collie	Rowden, E.	56·00	....	(c)43·00
		SILVER			
			Fine Ozs.		
		By-Product Gold Mining	196,207·08	....	112,636·15
		By-Product Copper Mining	6,886·10	....	3,863·80
			203,093·18	....	116,499·95
		SPODUMENE (See Lithium Ores)			
		TALC			
			Tons		
Private Property	South-West	Three Springs Talc Pty. Ltd.	4,669·15	.... (b) (c)	71,212·80
		TANTO/COLUMBITE ORES & CONCENTRATES (f) (g)			
				Ta2O5 Units	
M.C. 106	Pilbara	Hasleby, H. M. & H. B.	·29	16·42	852·90
M.C. 116	Pilbara	Wilson, L. J.	·25	14·72	610·20
M.C. 116	Pilbara	Tabba Tabba Mining Syndicate	·73	47·31	2,897·40
M.C. 621	Pilbara	Trigg Hill Mining Syndicate	·21	9·83	572·10
M.C. 107, etc.	Pilbara	Wilson, L. J.	·94	53·60	2,769·50
Crown Lands	Pilbara	Sundry Persons	1·48	48·83	1,875·75
M.C. 244, etc.	West Pilbara	Nomads Pty. Ltd.	·62	18·70	818·45
M.C. 62	Murchison	Goodwin, J.	·03	·48	12·45
M.C. 27	Yalgoo	Todd, Dan, and Breeze, B. F.	1·82	97·47	5,389·40
M.C. 35	Yalgoo	Meka Mining Sydnicate	·66	18·76	667·65
P.A. 2610	Yalgoo	Corney, R.	·05	1·64	68·25
M.C. 69, etc.	Greenbushes	Austin Bros.	(j)2·10	86·01	2,161·75
M.L. 647, etc.	Greenbushes	Vultan Syndicate	(j)4·52	160·37	4,409·35
Crown Lands	Greenbushes	Sundry Persons	(j) ·09	3·30	129·00
			13·79	577·44	(b)23,233·95
		TIN (f) (g)			
				Tons	
D.C. 53, etc.	Pilbara	Cooglegong Tin Pty. Ltd.	96·45	67·82	71,443·40
D.C. 201, etc.	Pilbara	Mineral Concentrates Pty. Ltd.	188·17	127·12	132,247·10
D.C. 254	Pilbara	Johnston, J. A.	88·41	62·95	66,301·85
D.C. 16, etc.	Pilbara	Leonard, H. V.	98·56	66·92	69,810·15
D.C. 276, etc.	Pilbara	D. D. Mining Co.	36·74	24·21	25,225·40
D.C. 257	Pilbara	Marble Bar Mining Co.	3·08	1·94	1,931·25
T.A. 13	Pilbara	Burney, R. & Rinaldi, A.	·54	·38	366·20
D.C. 305	Pilbara	Russell, H. H.	·81	·56	572·70
M.C. 106	Pilbara	Hasleby, H. M. & H. B.	·06	·02	21·05
P.A. 841L	Pilbara	Weatherall, A.	·09	·06	58·50
Crown Lands	Pilbara	Sundry Persons	15·28	10·66	10,938·30
M.C. 241, etc.	West Pilbara	Nomads Pty. Ltd.	1·08	·67	643·90
D.C. 1	Murchison	Goodwin, J.	·13	·09	97·75
M.C. 69, etc.	Greenbushes	Austin Bros.	20·34	12·36	12,120·85
M.L. 647, etc.	Greenbushes	Vultan Syndicate	26·49	16·26	16,244·90
			576·23	392·02	408,023·30 (b)

(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) Only results of shipments finalised during the period under review. (g) Metallic Content calculated on Assay basis. (h) Concentrates. (i) By-Product Gold Mining. (j) By-Product Tin Mining.

TABLE VI—TOTAL MINERAL OUTPUT OF WESTERN AUSTRALIA

Recorded mineral production of the State to 31st December, 1963, showing for each mineral the progressive quanity produced and value thereof, as reported to the Department of Mines ; including Gold (Mint and Export) as from 1886, and Other Minerals as from commencement of such records in 1899.

Mineral		Quantity	Value
			£
Abrasive Silica Stone	tons	1·50	9·00
Alunite (Crude Potash)	,,	9,073·05	215,864·72
Antimony Concentrates (a)	,,	9,829·69	242,497·00
Arsenic (a)	,,	38,674·08	747,205·00
Asbestos—			
Anthophyllite	,,	509·35	6,773·31
Chrysotile	,,	9,961·39	407,876·35
Crocidolite	,,	121,108·09	13,605,730·10
Tremolite	,,	1·00	25·00
Barytes	,,	2,867·06	18,876·55
Bauxite (e)	,,	36,741·00	....
Beryl	,,	3,526·49	458,122·74
Bismuth	lb.	12,384·00	3,770·30
Building Stone (i)—			
Chrysotile—Serpentine	tons	4·45	53·00
Granite (Facing Stone)	,,	112·00	3,460·00
Sandstone (Donnybrook)	,,	83·00	1,743·00
Spongolite	,,	1,063·00	4,868·00
Calcite	,,	5·00	25·00
Chromite	,,	14,419·05	208,296·75
Clays—			
Bentonite	,,	9,373·40	32,110·16
Brick, Pipe and Tile Clay (i)	,,	107,231·00	112,915·40
Cement Clay	,,	254,981·05	184,929·66
Fireclay	,,	236,905·51	254,781·03
Fullers Earth	,,	282·40	1,188·05
White Clay—			
Ball Clay	,,	21,181·60	62,572·30
Kaolin	,,	5,228·77	8,909·17
Coal	,,	32,863,889·19	49,001,491·53
Copper Ore and Concentrates	,,	282,788·03	3,118,092·45
Copper (Metallic By-Product) (a)	,,	(k)145·36	25,457·85
Corundum	,,	63·15	655·00
Cupreous Ore (Fertiliser)	,,	79,256·44	1,253,533·30
Diamonds (f)	Carats	....	24·00
Diatomaceous Earth (Calcined)	tons	426·00	6,160·75
Dolomite	,,	3,041·82	13,021·60
Emeralds (cut and rough)	carats	18,381·68	1,922·00
Emery	tons	21·15	375·00
Felspar	,,	63,013·61	223,502·01
Fergusonite	,,	0·30	391·40
Gadolinite	,,	1·00	112·00
Glass Sand	,,	106,712·61	77,047·61
Glauconite	,,	(j)6,467·00	(g)150,384·50
Gold (Mint and Export)	fine ozs.	64,166,694·48	483,332,430·00
Graphite	tons	153·20	1,304·20
Gypsum	,,	820,665·41	876,392·85
Iron Ore—			
For Pig Iron	,,	557,967·32	(g)7,343,792·06
For Export	,,	8,680,956·00	8,607,868·69
For Flux	,,	58,064·35	37,048·00
Jarosite	,,	9·54	37·50
Kyanite	,,	4,215·69	21,781·00
Lead Ores and Concentrates	,,	467,553·86	4,784,108·41
Limestone (i)	,,	183,609·51	109,690·50
Lithium Ores—			
Petalite	,,	657·98	4,934·80
Spodumene	,,	55·04	748·50
Magnesite	,,	25,252·41	131,331·39
Manganese—			
Metallurgical Grade	,,	625,019·30	8,176,867·76
Battery Grade	,,	1,914·25	39,502·10
Low Grade	,,	4,317·36	34,913·35
Mica	lb.	32,930·00	3,984·24
Mineral Beach Sands—			
Ilmenite Concentrates	tons	781,664·40	3,687,043·36
Monazite Concentrates	,,	3,355·67	114,110·45
Rutile Concentrates	,,	2,951·97	74,003·55
Leucoxene Concentrates	,,	1,877·00	26,230·57
Zircon Concentrates	,,	23,497·01	241,856·80
Crude Concentrates (Mixed)	,,	155·95	776·50
Ochre—			
Red	,,	8,870·76	97,343·80
Yellow	,,	447·60	2,977·75
Phosphatic Guano	,,	11,842·06	72,560·45
Pyrites Ore and Concentrates (For Sulphur) (b) (g)	,,	1,028,355·46	6,035,209·77
Quartz Grit	,,	829·50	700·35

TABLE VI.—Total Mineral Output of Western Australia—*continued*

Mineral		Quantity	Value
Semi-Precious Stones—			£
Chalcedony	lb.	448·00	200·00
Chrysoprase	,,	5·00	5·00
Opaline	,,	25·00	3·75
Prase	,,	2,240·00	40·00
Tiger Eye Opal	,,	120·00	97·00
Sillimanite	tons	2·00	13·00
Silver (*c*)	fine ozs.	10,667,926·06	2,314,433·98
Soapstone	tons	565·40	1,927·85
Talc	,,	45,759·00	619,692·68
Tanto-Columbite Ores and Concentrates	,,	531·92	558,357·59
Tin	,,	20,728·47	3,691,496·30
Tungsten Ore and Concentrates—			
Scheelite	,,	163·05	68,724·97
Wolfram	,,	303·42	61,758·65
Vermiculite	,,	1,832·96	11,830·60
Zinc (Metallic By-Product) (*d*)	,,	408·40	1,990·07
Zinc Ore (Fertiliser)	,,	20·00	100·00
Total Value to 31st December, 1963		....	£601,645,002·73 (*h*)

(*a*) By Product from Gold Mining.
(*b*) Part By-Product from Gold Mining.
(*c*) By-Product from Gold, Copper and Lead Mining.
(*d*) By-Product from Lead Mining.
(*e*) Value not yet available for publication.
(*f*) Quantity not recorded.
(*g*) Value of mineral recovered.
(*h*) Excludes Value of Bauxite.
(*i*) Incomplete—being only production reports from holdings under the Mining Act.
(*j*) Mineral Recovered.
(*k*) Assayed Metallic Content.

Footnote.—Comprehensive mineral production records maintained in the Statistical Branch of the Department of Mines show locality, producers, period, quantity, assayed or metallic content, and value of the various minerals listed above.

TABLE VII.

SHOWING AVERAGE NUMBER OF MEN EMPLOYED ABOVE AND UNDER GROUND IN THE LARGER GOLDMINING COMPANIES OPERATING IN WESTERN AUSTRALIA DURING THE YEARS FROM 1954 TO 1963 INCLUSIVE.‡

COMPANY	1954			1955			1956			1957			1958			1959			1960			1961			1962			1963		
	Above	Under	Total	Above	Under	Total	Above	Under	Total	Above	Under	Total	Above	Under	Total	Above	Under	Total	Above	Under	Total	Above	Under	Total	Above	Under	Total	Above	Under	Total
Anglo-Westralian Mining Pty.	28	6	34	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
†Boulder Perseverance, Ltd.	152	114	266	171	114	285	181	113	294	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Broken Hill Pty. Co. Ltd.	2	....	2	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Blue Spec Gold Mines, Ltd.	30	15	45	17	9	26	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Big Bell Mines Ltd.	179	167	346	44	16	60	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Consolidated Gold Area N.L.	1	2	3	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Comet Gold Mines Ltd.	4	2	6	3	....	3	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Central Norseman Gold Corporation N.L.	158	227	385	166	225	391	159	209	368	165	226	391	166	232	398	173	214	387	169	209	378	163	220	383	151	213	364	151	208	359
Eclipse Gold Mines N.L.	....	....	....	....	....	....	....	....	....	....	....	....	27	8	35	17	10	27	17	15	32	18	13	31	16	9	25	13	6	19
Golden Horseshoe (New) Ltd.	42	....	42	39	....	39	35	....	35	6	....	6	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Gold Mines of Kalgoorlie (Aust.) Ltd.	199	186	385	257	192	449	228	223	451	417	500	917	392	538	930	374	455	829	375	446	821	374	430	804	379	436	815	426	449	875
Great Boulder Pty. Ltd.	342	372	714	359	379	729	349	380	729	330	400	730	323	387	710	308	399	707	290	385	675	296	385	681	300	369	669	307	378	685
*Great Western Consolidated	191	150	341	224	271	441	232	270	502	220	223	443	220	241	461	207	218	425	197	174	371	164	124	288	144	92	236	58	28	86
Hill 50 Gold Mine N.L.	73	63	136	82	73	155	98	85	183	108	94	202	103	103	206	95	88	183	97	87	184	97	93	190	99	110	209	98	130	228
†Kalgoorlie Enterprise Ltd.	8	89	97	7	101	108	8	100	108	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
§Kalgurli Ore Treatment Co. Ltd.	78	....	78	65	....	65	40	....	40	33	....	33	28	....	28	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Lake View and Star Ltd.	488	498	986	482	487	969	471	523	994	460	517	977	433	525	958	451	535	986	432	513	945	417	514	931	411	527	938	417	545	962
Moonlight Wiluna Gold Mines Ltd. (Timoni)	42	34	76	39	33	72	37	32	69	36	31	67	35	31	66	31	27	58	31	24	55	30	30	60	33	39	72	35	38	73
Mountain View Gold N.L.	3	6	9	3	1	4	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Mt. Charlotte (Kalgoorlie) Gold Mines N.L.	3	2	5	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
North Kalgurli (1912) Ltd.	83	193	276	95	236	331	156	239	395	158	250	408	163	263	426	181	251	432	181	249	430	187	246	433	208	243	451	212	249	461
Paris Gold Mines Pty Ltd.	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	6	4	10	15	11	26	20	17	37	28	21	49	22	16	38
Gold Mines of Kalgoorlie (Aust.) Ltd. (Barbara and Bayleys Leases)	77	95	172	79	95	174	37	73	110	34	61	95	23	48	71	19	36	55	18	37	55	18	36	54	15	28	43	9	13	22
New Coolgardie Gold Mines N.L. (Callion Leases)....	9	42	51	8	35	43	3	11	14	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Ora Banda Amalgamated Ltd.	1	2	3	....	2	2	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Porphyry (1939) Gold Mines Ltd.	2	2	4	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Radio Gold Mines	5	5	10	6	6	12	6	6	12	7	7	14	6	6	12	6	6	12	6	6	12	6	5	11	5	5	10	6	5	11
†South Kalgurli Consolidated	64	106	170	53	99	152	13	84	97	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Sons of Gwalia Ltd.	102	138	240	102	146	248	105	156	261	107	146	253	109	142	251	99	137	236	106	139	245	103	143	246	96	137	233	98	119	217
Sunshine Reward Amalgamated Leases	8	7	15	7	4	11	8	7	15	2	....	2	8	3	11	5	2	7	3	1	4	2	2	4	2	2	4	2	2	4
Wiluna Gold Mines Ltd.	1	1	2	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
11 other Operators	734	495	1,229	634	388	1,022	544	407	951	498	349	847	476	313	789	521	398	919	469	290	759	509	283	792	524	321	845	520	341	861
State Average (inc. Diggers)	3,109	3,019	6,12	2,933	2,912	5,845	2,710	2,918	5,628	2,581	2,804	5,385	2,512	2,840	5,352	2,493	2,780	5,273	2,406	2,586	4,992	2,404	2,541	4,945	2,411	2,552	4,963	2,374	2,527	4,901

* Including Copperhead, Frasers, Nevoria, Corinthian and Pilot Groups.
Effective workers only and totally excluding non-workers for any reason whatsoever.

† Absorbed by Gold Mines of Kalgoorlie (Aust.) Ltd. from 1957.
§ Absorbed by Gold Mines of Kalgoorlie (Aust.) Ltd. from 1959.

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