Mines Department Western Australia

Annual Report 1966

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

REPORT OF THE
DEPARTMENT *of* MINES
WESTERN AUSTRALIA
FOR THE YEAR 1966

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1967

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To the Hon. Minister for Mines.

Sir,

I have the honour to submit the Annual Report of the Department of Mines of the State of Western Australia for the year 1966, together with reports from the officers controlling Sub-Departments, and Comparative Tables furnishing statistics relative to the Mining Industry.

I have the honour to be, Sir,

Your obedient Servant,

I. R. BERRY,

Under Secretary for Mines.

Perth, 1967.

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WESTERN AUSTRALIA

Report of the Department of Mines for the Year 1966

DIVISION I

Part 1.

The Honourable Minister for Mines:

I have the honour to submit for your information a report on the Mining Industry for the year 1966.

The estimated value of the entire mineral output of the State for the year was $75,963,058, an increase of $22,137,672 compared with that for the preceding year and constitutes an all time record. This is 41.13 per cent higher than the previous figure set in 1965.

The estimated value of gold received at the Perth Branch of the Royal Mint and exported in gold bearing material was $19,765,287, a decline of $956,877 when compared with the figure for 1965 and equalled only 25.75 per cent of the value of all minerals for 1966.

Full details of the value of mineral realised are set out in Tables 1 and 1 (a), Part 2.

Coal production from Collie during the year showed an increase of 67,353.85 tons, although there was a decrease of 15,004.10 tons in the tonnage of deep mine coal.

The overall average value per ton fell by 13.83 cents.

Figures for the last three years were:—

	1964	1965	1966
Tons	987,420	993,741	1,061,095
Total Value	$4,678,934	$4,409,972	$4,562,087
Average value per ton	$4.7385	$4.4377	$4.2994
Average effective workers	765	760	726
Proportion of deep mined coal	65·23%	51·15%	46·48%

Minerals other than Gold and Coal rose sharply in value to $51,635,684, an increase of $22,942,434 above that for 1965 to establish a new all time record, 79.96 per cent higher than the previous figure set in 1965. This huge increase was mainly due to increased production of Iron Ore (for export) and Alumina (from Bauxite). Substantial increases were also experienced in the realised values of Pig Iron, Manganese, Ilmenite, Asbestos, Copper Ore, Pyrites, Coal, Monazite and Zircon.

Dividends paid by Gold mining companies amounted to $1,951,044, a decline of $411,050 when compared with the previous year. (See Table 4, Part 2.)

To the end of 1965 the progressive total distributed in dividends by gold mining companies amounted to $149,529,610.

To the same date the progressive value of the whole mineral production of the State amounted to $A1,382,767,876 of which gold accounted for $A1,029,452,197. (See Table IV at back.)

Gold.

The quantity of gold advised as being received at the Perth Branch of the Royal Mint (627,314.65 fine ounces) together with that contained in gold-bearing material exported for treatment (1,462.05 fine ounces) totalled 628,776.7 fine ounces which was 30,660.28 fine ounces less than for the previous year. (See Table 1 (a) Part 2.)

The total gold yield reported directly to the Department by producers was 627,052 fine ounces, a decrease of 29,303 fine ounces.

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

The tonnage of ore reported to have been treated in 1966 viz. 2,619,016 tons, was 88,851 tons more than in the previous year but equalled only 61% of the State record tonnage of 4,291,709 treated in 1940.

The following tonnage increases were reported: East Coolgardie, 100,338 tons; Dundas, 5,977 tons and East Murchison 216 tons, but there was a general decline in the remaining goldfields. The increase in tonnage in the East Coolgardie Goldfield was due mainly to the Mt. Charlotte mine which treated 110,000 tons more than in 1965. Lake View & Star's tonnage was up 25,000 tons on the previous year's figure, while Great Boulder Gold Mines Limited treated 27,000 tons less.

The famous "Golden Mile" locality of Kalgoorlie-Boulder mining centres contained in the East Coolgardie Goldfield has to date treated a little over 89 million tons of ore for 36.55 million fine ounces of gold valued at a progressively estimated $578.20 million. These figures represent 57.39 per cent of the State's reported ore tonnage and 56.55 per cent of its gold.

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

In the Dundas Goldfield 188,691 tons of ore were treated of which Central Norseman Gold Corporation N.L. treated 188,647 tons. This tonnage was 5,068 tons more than the Company's tonnage for 1965 and averaged 10.4874 dwts, per ton being a slight improvement on the 1965 average of 10.418 dwts. per ton.

The gold mining industry is still labouring under the burden of producing a fixed-price commodity whilst faced with constantly rising costs. Difficulty is experienced in proving and maintaining sufficient payable reserves to preserve the life of the mines and with the great upsurge in mining activity throughout the State the labour problem is ever present.

West Australian gold included in sales on open dollar markets by the Gold Producers' Association Ltd. for the period from July, 1965 to September, 1966, totalled 806,252.79 fine ounces. The premium received therefrom in excess of Mint Value amounted to $A116,014, an overall average of 14.389 cents per fine ounce. That amount, less expenses, was distributed to the producer members during 1966 and approximated 13.275 cents per fine ounce.

Subsidy payments made by the Commonwealth Government during the year under the Gold Mining Subsidy Act 1954-1962 totalled $A3,550,492 an increase of $1,891,329 compared with the previous year. Of that amount $3,488,694 went to Large Producers and $61,798 went to Small Producers.

Other Minerals.

The tremendous increase in production of iron ore and alumina was reflected in royalties and during the year royalty totalling $721,954.10 as against $450,154.79 for the previous year was collected on prescribed minerals obtained from land held under the Mining Act and Special Acts.

Royalties for the year as compared with 1965 are shown hereunder:—

Mineral	Rate per ton	Royalty Collected 1965	Royalty Collected 1966
	cents	$	$
Asbestos	15	1.213.97	1,660.50
Barytes	5	37.20	58.28
Bauxite	5	35,315.19	46,577.99
Bentonite	5	26.50	25.65
Beryl	20	2.60	4.20
Building Stones	10	65.20	184.50
Clays	5	2,816.35	3,632.64
Coal	2·5	22,356.52	26,523.76
Diatomacious earth (calcined)	15	....	6.23
Felspar	5	45.10	75.40
Glass Sand	5	449.15	1,434.15
Gypsum	5	2,041.40	1,948.20
Ilmenite concentrates	10	25,432.30	37,202.45
Iron Ore	†	336,140.85	568,217.31
Leucoxene concentrates	10	32.15	78.00
Limestone	5	1,463.05	3,518.50
Magnesite	15	37.15	16.16
Manganese	15	14,588.92	16,317.95
Mineral Phosphates	10	....	1.50
Monazite	*	377.49	826.82
Ochre	5	25.05	....
Petalite	10	19.80	88.20
Pyrites	10	5,738.20	6,943.30
Rutile concentrates	15	22.50	72.00
Scheelite	*	....	3.94
Talc	‡	....	4,504.79
Tanto/Columbite	*	145.98	98.95
Tin concentrates	20	134.60	127.23
Zircon concentrates	10	1,627.57	1,805.50
		450,154.79	721,954.10

* One half per centum of the realised value F.O.R., or if exported, of the realised value F.O.B.

† Various rates according to type of ore.

‡ Various rates.

Koolanooka, Mt. Goldsworthy and Mt. Tom Price iron ore deposits all commenced production in 1966 and lifted exports of that ore to just over 4,000,000 tons valued at $18,268,833.

Western Aluminium N.L. continued to expand alumina production from Darling Range bauxite and the value of its product rose by $5,681,040 to a total of $14,589,120 for the year.

These increases were augmented by additional production in other minerals, notably pig iron, manganese and ilmenite the values of which each rose by over $750,000 and more than offset decreases in the value of tin production (down $324,944) and lead concentrates (down $288,230).

Confirmation of Barrow Island during the year as Australia's biggest commercial oil field was followed by announcement of a programme to drill 240 development wells on the Island and construct storage tanks and installations necessary to commence production in May 1967 at the rate of 9,000 barrels a day rising to 20,000 barrels a day within two years.

The programme included a six mile pipe-line from the Island to a sea terminal where oil would be pumped into tankers at the rate of 14,000 barrels an hour.

By that time $26,500,000 will have been invested in the exploration and development of the Barrow Island project where recoverable oil reserves were estimated at the end of the year to be at least 114,000,000 barrels.

Added to these momentous events was another of perhaps equally great significance to the State—the discovery of high-grade nickel ore in commercial quantity at Kambalda, some 35 miles southerly of Kalgoorlie.

This find by Western Mining Corporation Limited has not only resulted in the construction of a new townsite and plant at the mine to produce nickel concentrates, but has started one of the most intensive mineral searches in the history of W.A.

Throughout the eastern goldfields from Norseman to Wiluna large-scale exploration programmes involving modern geological, geophysical and geochemical methods were commenced by numerous companies, many of world-wide reputation. Local prospectors and residents also joined in the search for nickel and other base metals by adding their knowledge of surface indications to the scientific techniques of companies.

Active mineral exploration continued throughout the year in other parts of the State and the mining industry in W.A. is justified in looking forward to the future with great optimism.

PART 2—MINERALS.

COMPARATIVE MINERAL STATISTICS.

	1965	1966	Variation
GOLD—			
Reported to Department (Mine Production)—			
Ore (tons)	2,530,165	2,619,016	+ 88,851
Gold (fine ounces)	656,355	627,052	— 29,303
Average Grade (dwts. per ton)	5.188	4.786	— .402
Persons Engaged—			
(a) Effective Workers (excluding absentees)	4,094	4,053	— 41
(b) Total Pay Roll	4,468	4,411	— 57
Dividends ($A)	$2,362,094	$1,951,044	— $411,050
Mint and Export (Realised Production)—			
Gold (fine ounces)	659,437	628,777	— 30,660
Estimated Value ($A) (including Overseas Gold Sales Premium)	$20,722,164	$19,765,287	— $956,877
COAL—			
Reported to Department (Mine Production)—			
Tons	993,741	1,061,095	+ 67,354
Value ($A)	$4,409,972	$4,562,087	+ $152,115
Persons Engaged—			
Effective Workers (excluding absentees)	760	726	— 34
OTHER MINERALS—			
Reported to Department—			
Value ($A)	$28,693,250	*$51,635,684	+$22,942,434
Persons Engaged—			
Effective Workers (excluding absentees)	1,892	2,233	+ 341
TOTAL ALL MINERALS—			
Value ($A)	$53,825,386	*$75,963,058	+$22,137,672
Persons Engaged—			
Effective Workers†	6,746	7,012	+ 266

* All time record.

† Excluding Oil Search Men which engaged an average of 351 men in the field in 1965 and 361 men in the field in 1966.

TABLE 1

Quantity and Value of Minerals, other than Gold and Silver, produced during Years 1965 and 1966
Western Australia

Description of Minerals	1965 Quantity	1965 Value	1966 Quantity	1966 Value	Increase or Decrease for Year Compared with 1965 Quantity	Increase or Decrease for Year Compared with 1965 Value
	Tons	$A	Tons	$A	Tons	$A
Alumina (from Bauxite)	148,468.00	8,908,080	**243,152.00**	**14,589,120**	+ 94,684.00	+ 5,681,040
Asbestos (Chrysotile)	402.09	57,678	**119.01**	**19,326**	— 283.08	— 38,352
(Crocidolite)	9,279.94	1,746,079	**11,464.57**	**2,414,906**	+ 2,184.63	+ 668,827
Barytes	750.75	6,006	**1,809.65**	**26,660**	+ 1,058.90	+ 20,654
Beryl	13.08	2,891	**12.63**	**2,992**	— .45	+ 101
			Lb.		Lb.	
Bismuth	....	....	**95.70**	**88**	+ 95.70	+ 88
Building Stone* (Granite—Facing			Tons		Tons	
Stone)	106.00	4,240	**77.00**	**3,080**	— 29.00	— 1,160
(Quartzite)	....	....	**1,280.00**	**5,120**	+ 1,280.00	+ 5,120
(Quartz—Dead White)	245.00	4,110	....	....	— 245.00	— 4,110
(Sandstone)	221.00	1,326	**248.00**	**1,488**	+ 27.00	+ 162
(Slate)	185.00	1,515	....	....	— 185.00	— 1,515
(Spongolite)	529.00	4,786	**69.00**	**372**	— 460.00	— 4,414
Clays (Bentonite)	921.45	3,637	**563.50**	**2,582**	— 357.95	— 1,055
(Cement Clay)	25,989.00	58,561	**23,924.00**	**51,536**	— 2,065.00	— 7,025
(Fireclay)	61,102.00	84,335	**98,487.35**	**169,190**	+ 37,385.35	+ 84,855
(Fuller's Earth)....	63.00	534	....	....	— 63.00	— 534
(Kaolin)	190.50	965	**150.00**	**900**	— 40.50	— 65
(White Clay-Ball Clay) ..	1,440.00	11,412	**1,012.00**	**7,996**	— 428.00	— 3,416
(Brick, Pipe and Tile Clay)	135,396.00	191,442	**83,091.00**	**126,564**	— 52,305.00	— 64,878
Coal	993,740.80	4,409,972	**1,061,094.65**	**4,562,087**	+ 67,353.85	+ 152,115
Copper Ore and Concentrates	2,051.50	254,920	**3,268.29**	**518,134**	+ 1,216.79	+ 263,214
Cupreous Ore and Concentrates (Fertiliser)	1,078.76	99,234	**962.27**	**87,954**	— 116.49	— 11,280
Diatomaceous Earth	....	....	**45.50**	**1,955**	+ 45.50	+ 1,955
Dolomite	....	....	**5.00**	**75**	+ 5.00	+ 75
Felspar	1,384.00	19,488	**1,282.00**	**18,050**	— 102.00	— 1,438
Glass Sand	9,259.00	12,169	**28,219.00**	***16,482**	+ 18,960.00	+ *4,313
Gypsum	46,607.00	89,154	**41,884.00**	**79,873**	— 4,723.00	— 9,281
Iron Ore (Pig Iron recovered)	40,673.00	1,870,958	**56,075.00**	**2,865,043**	+ 15,402.00	+ 994,085
(Ore Exported)	2,240,939.00	4,444,538	**4,166,329.92**	**18,268,833**	+1,925,390.92	+ 13,824,295
Lead Ores and Concentrates	4,877.93	392,638	**2,681.30**	**104,408**	— 2,196.63	— 288,230
Limestone*	565,830.00	627,373	**577,435.70**	**650,666**	+ 11,605.70	+ 23,293
Lithium Ores (Petalite)	310.00	4,741	**933.00**	**14,124**	+ 623.00	+ 9,383
Magnesite	199.08	3,176	**135.07**	**1,959**	— 64.01	— 1,217
Manganese (Metallurgical, and Low Grades)	100,208.20	2,151,852	**136,747.94**	**3,047,909**	+ 36,539.74	+ 896,057
Mineral Beach Sands (Ilmenite)	392,891.22	3,852,377	**470,896.12**	**4,621,179**	+ 78,004.90	+ 768,802
(Monazite)	1,068.00	104,301	**1,894.62**	**221,277**	+ 826.62	+ 116,976
(Rutile)	225.00	15,989	**576.38**	**40,515**	+ 351.38	+ 24,526
(Leucoxene)	484.00	21,612	**755.89**	**31,273**	+ 271.89	+ 9,661
(Zircon)	27,879.67	750,268	**26,497.53**	**851,412**	— 1,382.14	+ 101,144
Ochre (Red)	186.65	2,240	**207.00**	**4,140**	+ 20.35	+ 1,900
Phosphatic Guano	15.00	300	....	....	— 15.00	— 300
Pyrites Ore and Concentrates (For Sulphur)	59,179.94	768,244	**76,136.22**	**1,023,071**	+ 16,956.28	+ 254,827
			Lb.		Lb.	
Semi Precious Stones	....	....	**655.00**	**504**	+ 655.00	+ 504
			Tons		Tons	
Talc	7,087.79	205,410	**9,155.34**	**231,625**	+ 2,067.55	+ 26,215
Tanto/Columbite Ores and Concentrates	9.87	17,746	**4.71**	**19,691**	— 5.16	+ 1,945
Tin	675.58	1,556,514	**589.01**	**1,231,570**	— 86.57	— 324,944
Tungsten Ores and Concentrate—Scheelite	....	....	**.52**	**771**	+ .52	— 771
Total	....	$A32,762,811	....	**$A55,936,500**	....	+$A23,173,689

TABLE 1 (*a*)

Quantity and Value of Gold and Silver Exported and Minted during Years 1965 and 1966

Description of Minerals	1965 Quantity	1965 Value	1966 Quantity	1966 Value	Increase or Decrease for Year Compared with 1965 Quantity	Increase or Decrease for Year Compared with 1965 Value
	Fine Oz.	$A	Fine Oz.	$A	Fine Oz.	$A
Gold (Exported and Minted)....	659,436.98	‡20,722,164	**628,776.70**	**‡19,765,287**	— 30,660.28	— 956,877
Silver (Exported and Minted)	290,622.68	340,411	**223,182.96**	**261,271**	— 67,439.72	— 79,140
Total	....	21,062,575	....	**20,026,558**	....	— 1,036,017
Grand Total	....	$A53,825,386	....	**$A75,963,058**	....	+$A22,137,672

* Incomplete.
‡ Including Overseas Gold Sales Premium.

TABLE 2

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

Goldfield	Reported Yield		Percentage for each Goldfield		Average Yield per ton of ore treated	
	1965	1966	1965	1966	1965*	1966*
	Fine Oz.	Fine Oz.	Per cent.	Per cent.	Dwts.	Dwts.
1. Kimberley	11	18	.002	.003	....	....
2. West Kimberley	....	....	....	....	....	....
3. Pilbara	508	917	.077	.146	11.043	15.764
4. West Pilbara	....	....	....	....	....	....
5. Ashburton	....	....	....	....	....	....
6. Gascoyne	260	350	.040	.056	53.061	48.962
7. Peak Hill	101	6	.015	.001	1.549	....
8. East Murchison	1,243	1,044	.189	.167	12.027	9.314
9. Murchison	55,477	42,472	8.452	6.773	6.596	5.235
10. Yalgoo	1	7	....	.001	....	....
11. Mt. Margaret	256	715	.039	.114	4.221	18.475
12. North Coolgardie	13,880	10,336	2.115	1.648	9.479	7.441
13. Broad Arrow	3,056	2,275	.466	.363	3.909	5.261
14. North-East Coolgardie	335	487	.051	.078	39.463	15.062
15. East Coolgardie	477,900	461,264	72.811	73.561	4.506	4.153
16. Coolgardie	4,628	5,636	.705	.899	23.463	29.385
17. Yilgarn	2,238	1,020	.341	.163	16.235	11.124
18. Dundas	95,393	99,063	14.534	15.798	10.442	10.500
19. Phillips River†	1,064	†1,389	.162	.221	....	....
20. South-West Mineral Field	....	....	....	....	....	....
21. State Generally	4	53	.001	.008	....	....
	656,355	627,052	100.000	100.000	5.188	‡4.786

* Gold at $A31.25 per fine oz. or $A1.5625 per pennyweight.
† By-product of Copper Mining.
‡ 1966 averages exclude dollied and alluvial gold.

TABLE 3

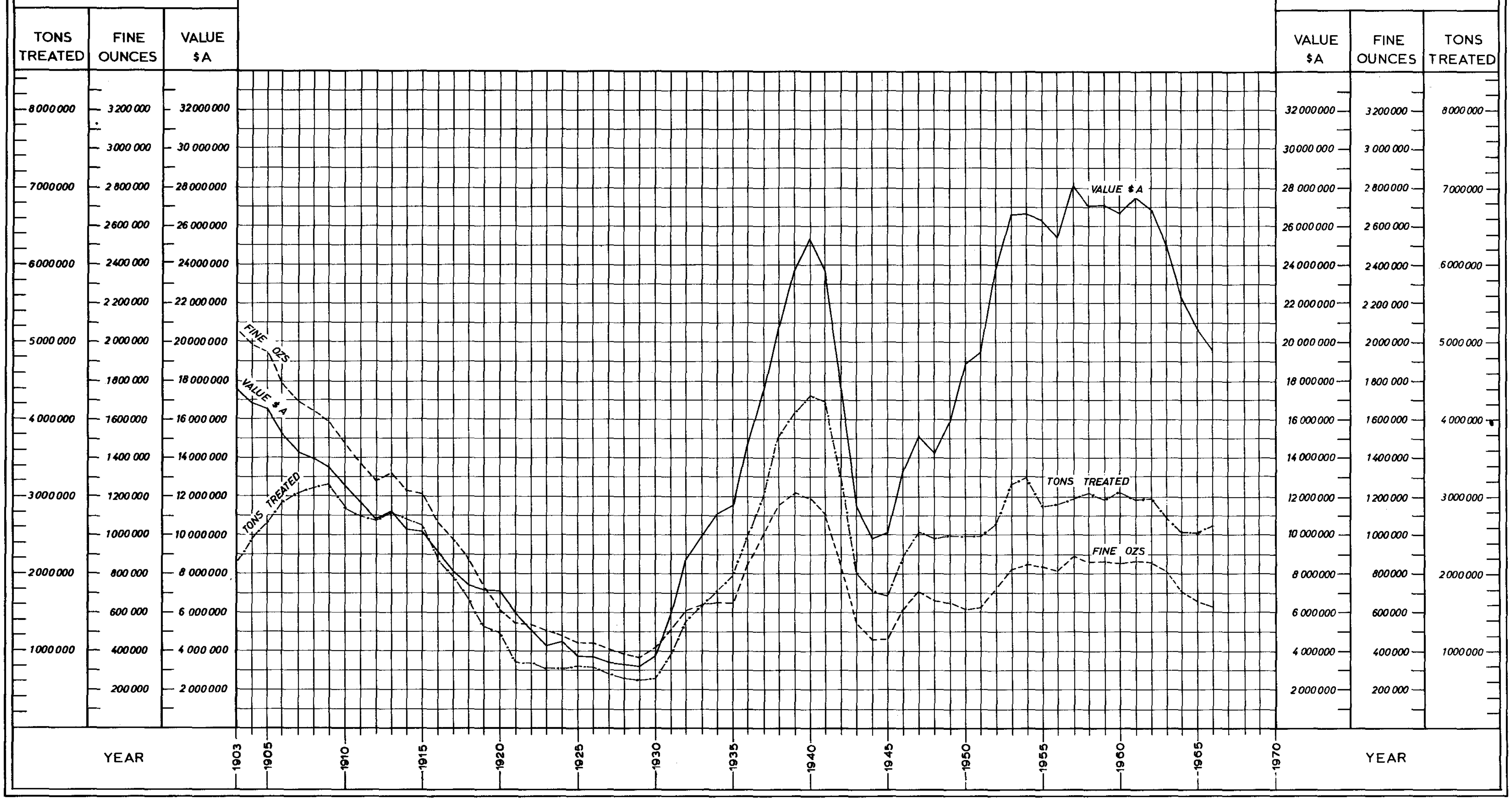
Output of Gold from the Commonwealth of Australia during 1966

State	Output of Gold	Value*†	Percentage of Total
	Fine oz.	$A	%
Western Australia	628,777	19,649,273	69.71
Victoria	‡19,263	601,969	2.15
New South Wales	8,985	280,781	.99
Queensland	127,148	3,973,338	14.10
Tasmania	32,655	1,020,469	3.62
South Australia	5	156	....
Northern Territory	85,120	2,660,000	9.43
Total	901,953	28,185,986	100.00

* $A31.25 per fine ounce.
† Exclusive of Overseas Gold Sales Premium by Gold Producers' Association.
‡ Subject to revision.

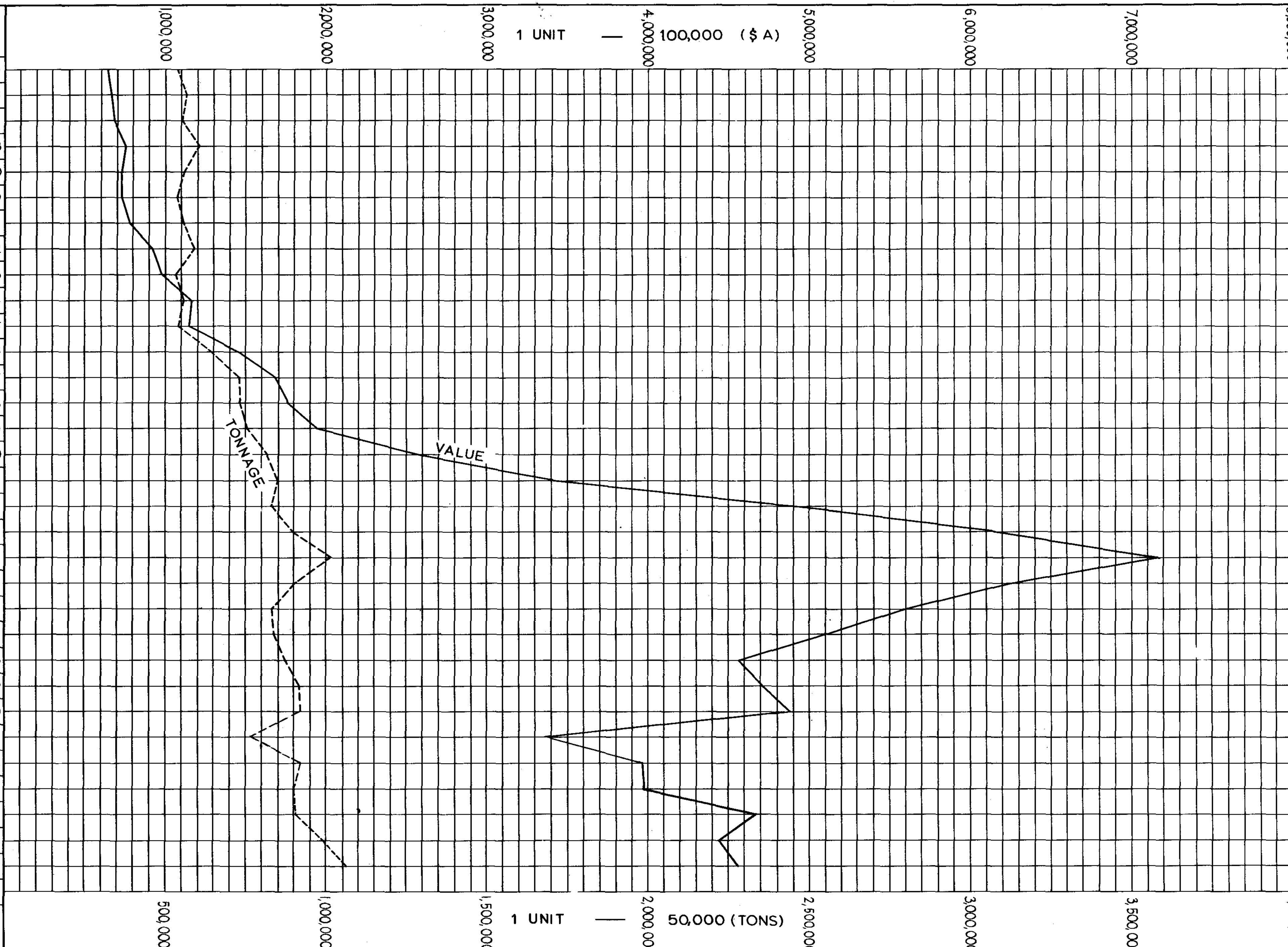
DIAGRAM OF GOLD OUTPUT

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



GRAPH OF COAL OUTPUT

SHOWING QUANTITIES AND VALUES AS REPORTED TO MINES DEPT.



TONS	VALUE $ A	YEAR
537188	636,026	1935
565075	663,130	1936
553510	680,888	1937
604793	750,176	1938
557535	725,622	1939
539427	729,000	1940
556574	778,556	1941
581176	922,990	1942
531546	979,442	1943
558322	1,166,150	1944
543363	1,145,792	1945
642287	1,460,208	1946
730506	1,680,498	1947
732938	1,760,472	1948
750594	1,944,490	1949
814351	2,575,498	1950
848475	3,433,576	1951
830461	4,914,592	1952
886182	6,146,146	1953
1,018,343	7,177,636	1954
903,792	6,264,148	1955
830008	5,595,012	1956
838660	5,105,310	1957
870882	4,560,398	1958
917434	4,713,064	1959
922393	4,878,390	1960
765,740	3,260,518	1961
919,112	3,961,556	1962
902,495	3,970,120	1963
987,420	4,678,934	1964
993,741	4,409,972	1965
1,061,095	4,562,087	1966
		1967
TONS		YEAR

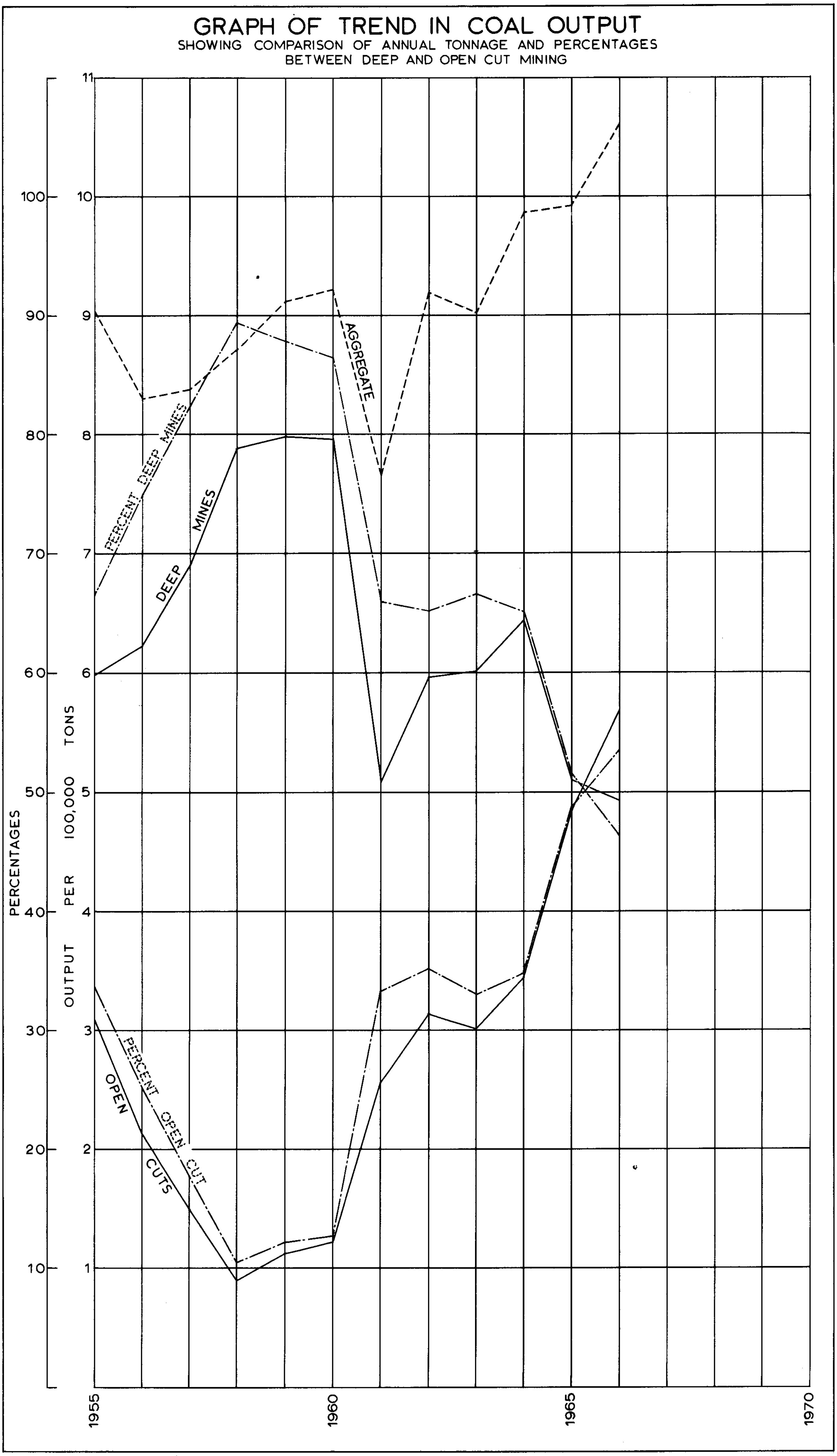

GRAPH OF TREND IN COAL OUTPUT
SHOWING COMPARISON OF ANNUAL TONNAGE AND PERCENTAGES
BETWEEN DEEP AND OPEN CUT MINING
PERCENTAGES
OUTPUT PER 100,000 TONS
AGGREGATE
PERCENT DEEP MINES
DEEP MINES
PERCENT OPEN CUT
OPEN CUTS
100
90
80
70
60
50
40
30
20
10
11
10
9
8
7
6
5
4
3
2
1
1955
1960
1965
1970

TABLE 4

Dividends, etc., paid by Western Australian Mining Companies during 1966, *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 1966	Dividends Paid Grand Total to end of 1966
		$A	$A
Pilbara	Various Companies	....	53,026
Peak Hill	do. do.	....	398,610
East Murchison	do. do.	....	3,828,106
Murchison	Hill 50 Gold Mines N.L.	90,000	15,721,252
	Various Companies	....	5,664,290
Mt. Margaret	do. do.	....	6,066,672
North Coolgardie	Moonlight Wiluna G.M's Ltd.	....	255,000
	Various Companies	....	1,425,102
Broad Arrow	do. do.	....	185,000
North-East Coolgardie	do. do.	....	258,986
East Coolgardie	Gold Mines of Kalgoorlie (Aust.) Ltd.	306,469	7,073,811
	Great Boulder G.M's Ltd.	....	19,750,050
	Lake View & Star Ltd.	437,500	(b) 22,849,000
	North Kalgurli (1912) Ltd.	207,075	7,188,637
	Various Companies	....	(a) 38,993,632
Coolgardie	do. do.	....	820,000
Yilgarn	do. do.	....	(c) 2,411,112
Dundas	Central Norseman Gold Corporation N.L.	910,000	15,015,000
	Various Companies	....	1,572,324
	Totals	1,951,044	149,529,610

(*a*) Excluding $A90,182 in bonuses and profit-sharing notes in years 1935–1936 by Boulder Perseverance Ltd., and $A110,000 Capital returned in year 1932 and $A86,000 in bonuses and profit-sharing notes in the year 1934 by Golden Horseshoe (New) Ltd.

(*b*) Excluding $A150,000 in bonuses and profit-sharing notes and $A187,500 Capital returned in 1932–1935.

(*c*) Excluding $A135,450 Capital returned by Edna May (W.A.) Amalgamated, N.L.

TABLE 5

Total Coal output from Collie River Mineral Field, 1965 *and* 1966, *estimated Value therefrom, Average Number of Men Employed and Output per Man.*

Year	Total Output	Estimated Value	Men Employed: Above Ground	Men Employed: Under Ground	Men Employed: Open Cuts	Output per Man Employed: In Open Cuts	Output per Man Employed: Under Ground	Output per Man Employed: Above and Under Ground
	Tons	$A	No.	No.	No.	Tons	Tons	Tons
Deep Mining—								
1965	508,260	2,960,616	110	467	....	....	1,088	881
1966	493,256	2,914,140	98	419	....	....	1,177	954
Open Cut Mining—								
1965	485,481	1,449,356	....	....	183	2,653	....	....
1966	567,839	1,647,947	....	....	209	2,717	....	....
Totals—								In all mines
1965	993,741	4,409,972	110	467	183	....	....	1,308
1966	1,061,095	4,562,087	98	419	209	....	....	1,462

LEASES AND OTHER HOLDINGS UNDER VARIOUS ACTS RELATING TO MINING.

TABLE 6

MINING ACT 1904.

Total Number and Acreage of Mining Tenements and Temporary Reserves applied for during 1966 *and in force as at* 31*st December,* 1966 (*Compared with* 1965)

—	Applied for				In Force			
	1965		**1966**		1965		**1966**	
	No.	Acreage	No.	Acreage	No.	Acreage	No.	Acreage
Gold—								
Gold Mining Leases	73	1,356	**89**	**1,608**	960	18,032	**1,008**	**18,647**
Dredging Claims	3	315	**5**	**1,142**	2	19	**2**	**312**
Prospecting Areas	460	7,968	**450**	**7,963**	384	6,725	**343**	**6,135**
Temporary Reserves	228	68,700	**128**	**40,972**	475	141,198	**395**	**115,330**
Totals	764	78,339	**672**	**51,685**	1,821	165,974	**1,748**	**140,424**
Coal—								
Coal Mining Leases	21	5,463	....	....	49	14,467	**49**	**14,367**
Prospecting Areas	....	....	....	....	....	....	....	....
Temporary Reserves	11	1,863,040	**1**	**369,920**	14	4,883,840	**12**	**2,736,640**
Totals	32	1,868,503	**1**	**369,920**	63	4,898,307	**61**	**2,751,007**
Other Minerals—								
Mineral Leases	72	16,955	**145**	**30,509**	135	9,836	**233**	**34,180**
Dredging Claims	149	20,817	**81**	**7,206**	352	33,560	**422**	**37,497**
Mineral Claims	373	55,654	**534**	**123,148**	1,345	141,265	**1,574**	**187,022**
Prospecting Areas	172	3,892	**140**	**6,294**	124	2,728	**134**	**5,790**
Temporary Reserves	215	217,289,440	**241**	**137,818,240**	256	103,536,000	**353**	**133,037,440**
Totals	981	217,386,758	**1,141**	**137,985,397**	2,212	103,723,389	**2,716**	**133,301,929**
Other Holdings—								
Miner's Homestead Leases	11	2,656	**17**	**4,506**	343	31,702	**349**	**34,129**
Miscellaneous Leases	6	112	**15**	**169**	117	1,719	**117**	**1,715**
Residence Areas	1	1	**2**	**2**	71	23	**66**	**20**
Business Areas	....	....	**1**	**2**	27	16	**26**	**16**
Machinery Areas	....	....	**2**	**6**	25	67	**26**	**69**
Tailings Areas	....	....	....	....	25	97	**24**	**96**
Garden Areas	2	6	**2**	**10**	67	207	**58**	**180**
Quarrying Areas	2	29	**1**	**10**	13	180	**9**	**102**
Water Rights	22	543	**7**	**296**	143	2,630	**142**	**3,173**
Licenses to Treat Tailings	40	....	**21**	....	34	....	**35**	....
Totals	84	3,347	**68**	**5,001**	865	36,641	**852**	**39,500**
Grand Totals	1,861	219,336,947	**1,882**	**138,412,003**	4,961	108,824,311	**5,377**	**136,232,860**

TABLE 6 (a)

SPECIAL ACTS

Total Number and Acreage of Mining Leases applied for during 1966 *and in force as at* 31*st December,* 1966 (*Compared with* 1965)

Holding	Applied for				In Force			
	1965		**1966**		1965		**1966**	
	No.	Acreage	No.	Acreage	No.	Acreage	No.	Acreage
Mineral Leases	232	201,461	**7**	**494,750**	2	1,816,960	**4**	**3,176,320**

TABLE 6 (b)

PETROLEUM ACT

Total Number and Acreage of Permits to Explore and Licenses to Prospect applied for during 1966 *and in force as at* 31*st December*, 1966 (*Compared with* 1965)

Holding	Applied for				In Force			
	1965		**1966**		1965		**1966**	
	No.	Acreage	No.	Acreage	No.	Acreage	No.	Acreage
Permits to Explore	2	4,108,800	**18**	**143,422,720**	41	484,947,200	**36**	**421,675,520**
Licenses to Prospect	30	3,817,600	**25**	**3,077,760**	57	6,722,560	**73**	**8,318,080**
Totals	32	7,926,400	**43**	**146,500,480**	98	491,669,760	**109**	**429,993,600**

TABLE 6 (c)

MINING ACT, 1904

Total Area of Leases Applied for, Approved and in Force as at 31*st December*, 1966 *in each Goldfield and Mineral Field*

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
	Acres	Acres	Acres	Acres	Acres	Acres	Acres	Acres	Acres	Acres	Acres	Acres
Ashburton	....	....	....	....	....	136	....	....	....	....	....	5
Black Range	....	....	65	....	....	....	....	....	....	....	....	....
Broad Arrow	108	113	331	2,100	300	300	....	....	....	....	....	5
Bulong	....	....	48	....	....	....	....	....	....	....	....	3
Collie	....	....	....	....	....	13,847	....	....	....	20	....	....
Private Property	....	....	....	....	....	520	....	....	....	....	....	....
Coolgardie	473	483	1,143	16,660	9,028	9,089	475	1,000	1,859	....	....	60
Cue	....	....	36	....	....	....	....	....	1,234	....	....	....
Day Dawn	....	....	438	....	....	....	....	....	20	....	....	....
Dundas	....	....	6,898	....	....	....	....	....	909	....	....	....
East Coolgardie	93	133	5,497	....	....	....	120	4	3,357	96	96	1,180
Gascoyne	....	39	89	....	....	8	....	....	....	....	....	....
Greenbushes	....	....	....	47	18	6,306	....	....	588	....	....	....
Kanowna	38	....	22	....	....	....	....	....	702	....	....	....
Kimberley	....	....	34	....	....	....	....	....	....	....	....	....
Kunanalling	....	....	47	....	....	....	....	....	520	....	....	....
Kurnalpi	....	12	72	....	....	....	....	....	....	....	....	....
Lawlers	72	24	332	....	....	....	....	....	1,110	....	....	24
Marble Bar	379	134	407	....	....	40	1,000	12	27	50	....	86
Meekatharra	36	12	82	300	....	....	....	....	1,866	....	....	1
Menzies	24	24	388	....	....	....	....	....	740	....	....	10
Mount Magnet	143	119	938	....	....	38	....	....	30	....	....	....
Mount Malcolm	24	....	164	....	....	....	....	....	1,270	....	....	....
Mount Margaret	46	70	88	....	....	....	11	....	58	....	....	....
Mount Morgans	24	24	105	....	29	29	....	....	....	....	....	....
Niagara	....	....	29	....	....	....	....	....	20	....	....	....
Northampton	....	....	....	172	45	152	....	....	53	....	....	....
Private Property	....	....	....	20	....	33	....	....	....	....	....	....
Nullagine	....	....	198	....	....	....	....	....	22	2	2	50
Peak Hill	....	....	32	96	....	441	....	....	250	....	....	5
Phillips River	....	....	21	....	317	563	680	500	14,634	....	....	....
Private Property	....	....	....	....	....	....	....	....	....	....	....	....
South-West	....	....	48	....	....	....	....	....	....	....	....	2
Private Property	....	....	....	276	275	1,357	....	....	....	....	....	....
Ularring	....	....	120	....	....	....	....	....	20	1	....	....
West Kimberley	....	....	....	....	....	755	500	....	....	....	....	75
West Pilbara	4	....	62	10,763	....	132	....	....	11	....	....	141
Wiluna	....	....	....	30	30	30	....	....	3,876	....	....	11
Yalgoo	24	....	52	....	109	....	....	....	10	....	....	....
Yerilla	....	....	352	....	....	....	....	....	10	....	....	....
Yilgarn	120	33	461	45	45	141	1,720	500	933	....	....	57
Private Property	....	....	48	....	....	....	....	....	....	....	....	....
Outside Proclaimed	....	....	....	....	200	200	....	....	....	....	....	....
Totals	1,608	1,220	18,647	30,509	10,396	34,117	4,506	2,016	34,129	169	98	1,715

TABLE 6 (d)

MINING ACT, 1904

Number and Area of Leases in Force as at 31st December, 1966 *on Crown Land and on Private Property in each Goldfield and Mineral Field*

Goldfield or Mineral Field District	Gold Mining Leases		Mineral Leases		Miner's Homestead Leases		Miscellaneous Leases	
	Number	Acres	Number	Acres	Number	Acres	Number	Acres
Ashburton	....	....	7	136	....	....	1	5
Black Range	6	65	....	....	....	....	....	....
Broad Arrow	22	331	1	300	....	....	1	5
Bulong	3	48	....	....	....	....	1	3
Collie	....	....	47	13,847	....	....	....	....
(Private Property)	....	....	2	520	....	....	....	....
Coolgardie	61	1,143	45	9,089	22	1,859	6	60
Cue	3	36	....	....	6	1,234	....	....
Day Dawn	21	438	....	....	1	20	....	....
Dundas	312	6,898	....	....	19	909	....	....
East Coolgardie	310	5,497	....	....	68	3,357	67	1,180
Gascoyne	5	89	1	8	....	....	....	....
Greenbushes	....	....	42	6,306	11	588	....	....
Kanowna	2	22	....	....	12	702	....	....
Kimberley	2	34	....	....	....	....	....	....
Kunanalling	2	47	....	....	2	520	....	....
Kurnalpi	3	72	....	....	....	....	....	....
Lawlers	18	332	....	....	5	1,110	1	24
Marble Bar	33	407	2	40	4	27	8	86
Meekatharra	6	82	....	....	11	1,866	1	1
Menzies	23	388	....	....	7	740	1	10
Mount Magnet	61	938	4	38	2	30	....	....
Mount Malcolm	8	164	....	....	9	1,270	....	....
Mount Margaret	4	88	....	....	7	58	....	....
Mount Morgans	5	105	1	29	....	....	....	....
Niagara	2	29	....	....	1	20	....	....
Northampton	....	....	7	152	1	53	....	....
(Private Property)	....	....	2	33	....	....	....	....
Nullagine	11	198	....	....	2	22	3	50
Peak Hill	2	32	14	441	5	250	1	5
Phillips River	2	21	13	563	107	14,634	....	....
(Private Property)	....	....	....	....	....	....	....	....
South-West	2	48	....	....	....	....	1	2
(Private Property)	....	....	6	1,357	....	....	....	....
Ularring	9	120	....	....	1	20	....	....
West Kimberley	....	....	23	755	....	....	5	75
West Pilbara	12	62	10	132	2	11	7	141
Wiluna	....	....	1	30	17	3,876	3	11
Yalgoo	4	52	....	....	1	10	....	....
Yerilla	18	352	....	....	1	10	....	....
Yilgarn	33	461	3	141	25	933	10	57
(Private Property)	3	48	....	....	....	....	....	....
Outside Proclaimed	....	....	2	200	....	....	....	....
Totals	1,008	18,647	233	34,117	349	34,129	117	1,715

	Number	Acres
Gold Mining Leases on Crown Land	1,005	18,599
Gold Mining Leases on Private Property	3	48
Mineral Leases on Crown Land	223	32,270
Mineral Leases on Private Property	10	1,910
Miner's Homestead Leases on Crown Land	349	34,129
Other Leases on Crown Land	117	1,715

TABLE 6 (e)

MINING ACT, 1904

Total Area of Claims and Authorised Holdings Applied for, Granted and in Force as at 31st December, 1966 in each Goldfield and Mineral Field

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	
	Acres	Acres	Acres	Acres	Acres	Acres	Acres	Acres	Acres	
Ashburton	40	40	40	5,906	4,689	8,283	....	4,729	....	32
Black Range	108	96	72	600	600	624	....	....	1	10
Broad Arrow	935	776	714	3,168	1,981	1,957	....	....	10	15
Bulong	293	217	177	3,660	72	195	....	....	....	....
Collie	....	....	....	....	....	....	....	....	....	....
Private Property	....	....	....	....	....	....	....	....	....	....
Coolgardie	1,769	1,386	1,218	4,711	3,828	5,023	10	....	25	....
Cue	118	118	118	118	118	342	....	....	4	64
Day Dawn	60	48	48	48	48	24	....	....	20	....
Dundas	200	200	176	693	1,569	4,773	....	....	17	104
East Coolgardie	552	502	512	7,025	4,361	4,489	1	....	157	977
Gascoyne	....	....	....	1,117	1,117	3,730	....	....	....	103
Greenbushes	....	....	....	....	....	485	....	....	69	13
Kanowna	235	219	191	3,600	3,330	3,300	....	....	8	....
Kimberley	....	....	....	1,500	1,500	101	....	....	....	18
Kunanalling	226	106	94	1,210	1,210	1,210	....	....	25	....
Kurnalpi	132	132	132	6,707	5,807	5,807	....	....	....	....
Lawlers	238	238	214	2,400	....	42	....	....	12	....
Marble Bar	500	453	437	17,119	16,390	75,164	275	566	1,457	321
Meekatharra	287	247	247	1,861	913	1,219	....	....	5	97
Menzies	319	229	205	720	2,556	2,856	....	....	23	39
Mount Magnet	286	247	247	328	24	24	....	....	33	101
Mount Malcolm	248	248	176	3,396	2,496	2,496	....	....	193	....
Mount Margaret	72	48	48	624	24	24	....	....	4	....
Mount Morgans	12	12	12	4,284	1,212	1,260	....	....	1	....
Niagara	56	20	12	....	....	....	....	....	6	....
Northampton	....	....	....	558	2,344	3,574	1	....	1	30
Private Property	....	....	....	560	....	30	....	....	....	....
Nullagine	1,208	366	366	1,047	1,110	7,624	....	....	57	14
Peak Hill	12	12	12	5,707	5,353	6,376	....	....	9	....
Phillips River	48	24	....	186	128	4,203	....	....	11	37
Private Property	....	....	....	....	....	424	....	....	....	....
South-West	24	39	39	14,833	3,829	22,901	....	....	....	1,191
Private Property	63	....	....	27,472	2,683	20,307	....	....	....	....
Ularring	96	96	116	....	....	24	....	....	13	....
West Kimberley	....	....	....	336	....	48	10	....	53	8
West Pilbara	....	....	....	1,000	1,431	28,545	25	....	44	34
Wiluna	48	48	48	72	96	96	....	....	1,334	....
Yalgoo	280	232	208	4,403	5,873	6,773	....	....	22	17
Yerilla	36	36	36	2,100	2,100	2,100	....	....	12	3
Yilgarn	652	560	532	7,476	153	3,525	2	2	25	183
Private Property	....	....	....	....	....	....	....	....	....	....
Outside Proclaimed	....	....	....	576	336	336	....	....	....	....
Private Property	....	....	....	....	....	....	....	....	....	....
Totals	9,153	6,995	6,447	137,121	79,281	230,314	324	5,297	3,651	3,411

TABLE 6 (f)
MINING ACT, 1904

Number and Area of Claims and Authorised Holdings in Force as at 31st December, 1966 in each Goldfield and Mineral Field

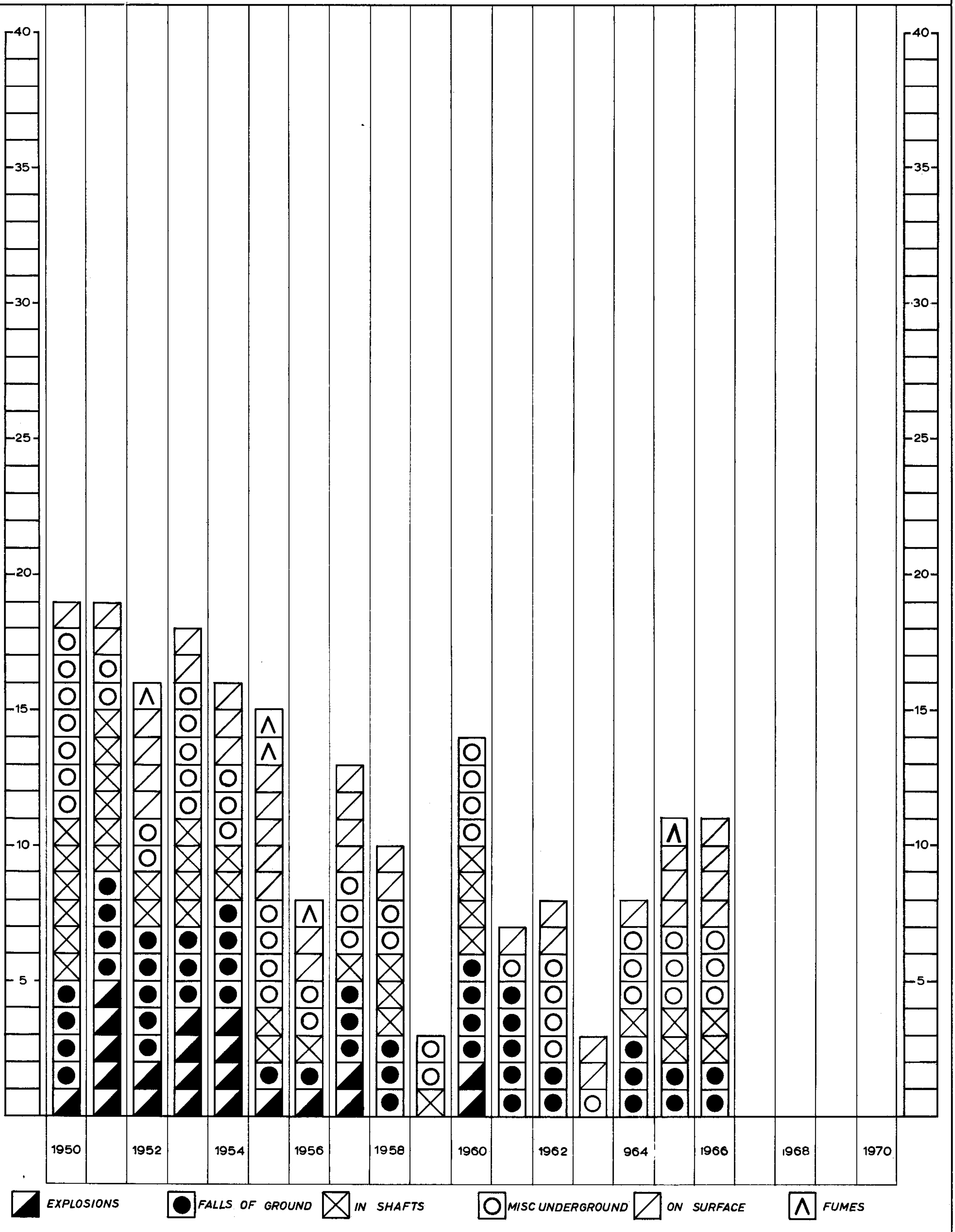
Goldfield or Mineral Field District	P.A.'s		D.C.'s		M.C.'s		R.A.'s		B.A.'s		M.A.'s		T.A.'s		G.A.'s		W.R.'s		Qu. Area	
	Number	Acres	Number	Acres	Number	Acres	Number	Acres	Number	Acres	Number	Acres	Number	Acres	Number	Acres	Number	Acres	Number	Acres
Ashburton	8	143	....	....	38	8,180	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Black Range	3	72	....	....	3	624	4	1	....	....	....	....	....	....	....	....	....	....	....	....
Broad Arrow	45	794	....	....	7	1,877	1	1	1	1	....	....	....	....	....	....	3	8	....	....
Bulong	11	177	....	....	5	195	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Collie	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Private Property	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Coolgardie	77	1,347	....	....	29	4,894	4	1	....	....	1	1	....	....	2	6	5	17	....	....
Cue	14	236	....	....	10	224	4	1	....	....	....	....	....	....	....	....	1	3	....	....
Day Dawn	3	72	....	....	....	....	....	....	....	....	....	....	....	....	4	20	....	....	....	....
Dundas	27	569	....	....	53	4,380	....	....	....	....	....	....	1	5	....	....	2	12	....	....
East Coolgardie	34	560	....	....	16	4,441	30	7	....	....	1	2	12	56	4	17	12	33	4	42
Gascoyne	3	68	....	....	31	3,662	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Greenbushes	....	....	....	....	8	485	1	1	....	....	....	....	....	....	9	37	2	31	....	....
Kanowna	11	191	....	....	11	3,300	....	....	....	....	....	....	....	....	2	7	1	1	....	....
Kimberley	....	....	....	....	1	98	....	....	....	....	....	....	....	....	1	3	....	....	....	....
Kunanalling	6	94	....	....	5	1,210	....	....	....	....	....	....	....	....	....	....	3	25	....	....
Kurnalpi	6	132	....	....	20	5,807	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Lawlers	9	214	....	....	3	42	....	....	....	....	2	6	1	5	....	....	1	1	....	....
Marble Bar	35	735	403	35,345	363	39,521	2	1	6	6	8	25	2	10	....	....	41	1,391	1	24
Meekatharra	18	354	....	....	7	1,112	....	....	....	....	....	....	....	....	....	....	2	5	....	....
Menzies	15	217	....	....	14	2,844	....	....	....	....	1	1	....	....	3	9	5	13	....	....
Mount Magnet	15	271	....	....	....	....	1	1	....	....	....	....	....	....	16	27	3	5	....	....
Mount Malcolm	12	272	....	....	8	2,400	....	....	....	....	....	....	....	....	7	29	10	164	....	....
Mount Margaret	3	72	....	....	....	....	....	....	....	....	....	....	....	....	....	....	4	4	....	....
Mount Morgans	4	72	....	....	4	1,200	....	....	....	....	....	....	....	....	....	....	1	1	....	....
Niagara	1	12	....	....	....	....	....	....	....	....	....	....	....	....	....	....	3	6	....	....
Northampton	2	48	....	....	25	3,526	....	....	....	....	....	....	....	....	....	....	1	1	....	....
Private Property	1	20	....	....	1	10	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Nullagine	9	130	1	300	263	7,560	....	....	....	....	2	1	2	2	3	6	15	48	....	....
Peak Hill	4	84	....	....	54	6,304	1	1	....	....	2	8	....	....	....	....	....	....	....	....
Phillips River	2	48	....	....	43	4,155	....	....	....	....	1	2	2	4	....	....	....	....	1	5
Private Property	....	....	....	....	3	424	....	....	....	....	....	....	....	....	....	....	....	....	....	....
South-West	4	2,863	9	1,555	167	18,520	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Private Property	1	10	5	521	138	19,776	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Ularring	6	140	....	....	....	....	....	....	....	....	1	1	2	4	....	....	7	8	....	....
West Kimberley	....	....	....	....	1	48	....	....	....	....	2	10	....	....	....	....	1	12	3	31
West Pilbara	21	468	6	88	174	27,989	4	1	11	6	....	....	....	....	....	....	8	37	....	....
Wiluna	6	144	....	....	....	....	....	....	....	....	1	1	1	3	1	5	5	1,325	....	....
Yalgoo	16	368	....	....	27	6,613	....	....	6	2	1	5	1	5	....	....	1	10	....	....
Yerilla	3	36	....	....	7	2,100	....	....	....	....	....	....	....	....	....	....	5	12	....	....
Yilgarn	33	556	....	....	35	3,501	14	4	2	1	3	6	....	....	6	14	....	....	....	....
Private Property	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Outside Proclaimed	7	336	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Private Property	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Totals	475	11,925	424	37,809	1,574	187,022	66	20	26	16	26	69	24	96	58	180	142	3,173	9	102

	No.	Acres
Prospecting Areas on Crown Land	474	11,905
Prospecting Areas on Private Property	1	20
Dredging Claims on Crown Land	419	37,288
Dredging Claims on Private Property	5	521

	No.	Acres
Mineral Claims on Crown Land	1,432	166,812
Mineral Claims on Private Property	142	20,210
Authorised Holdings on Crown Land	351	3,656

DIAGRAM OF ACCIDENTS

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



MEN EMPLOYED

TABLE 7

Average number of Men reported as engaged in Mining during 1965 and 1966

Goldfield	District	Total 1965	Total 1966
Kimberley	....	....	....
West Kimberley	....	....	....
Pilbara	Marble Bar	26	30
	Nullagine	14	10
West Pilbara	....	1	2
Ashburton	....	....	....
Gascoyne	....	2	2
Peak Hill	....	2	1
East Murchison	Lawlers	34	37
	Wiluna	4	5
	Black Range	6	4
Murchison	Cue	32	32
	Meekatharra	10	7
	Day Dawn	7	9
	Mt. Magnet	208	193
Yalgoo	....	1	3
Mt. Margaret	Mt. Morgans	12	13
	Mt. Malcolm	25	28
	Mt. Margaret	6	12
North Coolgardie	Menzies	102	94
	Ularring	18	24
	Niagara	4	6
	Yerilla	9	10
Broad Arrow	....	85	80
North-East Coolgardie	Kanowna	13	13
	Kurnalpi	8	10
East Coolgardie	East Coolgardie	2,883	2,848
	Bulong	9	11
Coolgardie	Coolgardie	108	119
	Kunanalling	19	19
Yilgarn	....	136	129
Dundas	....	310	302
Phillips River	....	....	....
South-West Mineral Field	....	....	....
Total, Gold Mining	....	4,094	4,053

	1965	1966
Minerals Other than Gold—		
Alumina (from Bauxite)	317	389
Asbestos	366	342
Barytes	1	7
Beryl	6	6
Building Stone	9	10
Clays	20	17
Coal	760	726
Copper	64	73
Cupreous Ore (Fertiliser)	43	26
Felspar	6	7
Glass Sand	3	3
Gypsum	14	13
Iron Ore	357	562
Lead	33	27
Limestone	19	21
Manganese	68	35
Mineral Beach Sands (Ilmenite, etc.)	311	322
Nickel	....	60
Ochre	....	1
Pyrites	94	102
Talc	5	6
Tanto/Columbite	9	7
Tin	147	222
Total, Other Minerals	2,652	2,984

PART 3—STATE AID TO MINING.

(a) *State Batteries.*

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

From inception to the end of 1966, gold, tin, tungsten, lead, copper and tantalite ores to the value of $38,925,492 have been treated at the State Batteries. Included in the above amount is $15,133,043 gold premium and $91,697 premium paid by sales of gold by the Gold Producers Association Ltd. $37,581,240 came from 3,532,258 tons of gold ore, $214,047 from 83,356¼ tons of tin ore, $38,471 from 3,967¾ tons tungsten ore, $1,053,297 from 44,252¼ tons lead ore, $11,932 from 220½ tons of copper ore and $26,505 from 224 tons of tantalite ore.

During the year 29,422¼ tons of gold ores were crushed for 15,260 ozs bullion, estimated to contain 12,932 ozs. fine gold, equal to 8 dwts, 19 grs. per ton. The average value of sands after malgamation was 3 dwts. 6 grns, per ton, making the average head value 12 dwts. 1 grs. per ton. Cyanide plants produced 2,365 ozs, fine gold, giving a total estimated production for the year of 15,297 ozs, fine gold valued at $480,514.

The working expenditure for the year for all plants was $444,309 and the revenue was $76,921 giving a working loss of $367,388 which does not include depreciation or interest. Since the inception of State Batteries, the Capital expenditure has been $1,737,262 made up of $1,378,037 from General Loan Funds; $274,409 from Consolidated Revenue; $57,244 from Assistance to Gold Mining Industry: and $27,572 from Assistance to Metalliferous Mining.

Head Office expenditure including Workers Compensation Insurance and Pay Roll Tax was $57,930 compared with $56,684 for 1966.

The working expenditure from inception to the end of 1966 exceeds revenue by $4,879,994.

(b) *Prospecting Scheme.*

At the end of the year 36 men were in receipt of prospecting assistance as compared with 32 at the end of 1965.

Total expenditure for the year was $15,894 and refunds amounted to only $2,852.

Assisted prospectors crushed 1,065 tons of ore for 417 ozs. of gold.

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

Expenditure	$934,779
Refunds	$184,150
Ore Crushed	121,926 tons
Gold Won	57,015 ozs.

The rate of assistance was increased during the year to $17.50 per man per week in the more isolated areas and to $15 per week in those nearer to Perth.

(c) *Geological Survey of Western Australia.*

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

In common with other Branches of the Department, the Survey's services were in great demand during the year particularly in regard to nickel and base metal exploration and the increasing search for oil.

Information on localities, on known mineral occurrences and on the progress and results of geological mapping was given by the Survey together with general advice regarding mineral potential.

Assessment of the State's groundwater resources continued and the Hydrology Division again provided assistance to Government Departments and private landholders in their search for water supplies.

Engineering geology services were again provided in connection with dam sites in the Kimberley, Pilbara and Gascoyne fields, while regional mapping and appraisal of mineral resources continued as rapidly as possible during the year.

PART 4—SCHOOL OF MINES.

(a) *Kalgoorlie.*

Enrolments at the School continued the downward trend of 1964 and 1965, the number of students in 1966 falling to 240 as compared with 275 in the previous year and 329 in 1964.

This is regrettable in view of the great activity in the mining industry with its consequent need for trained men and it is hoped that the construction of new and modern school buildings will help to arrest the trend by attracting more students to choose careers in this field.

Stage 1A of a comprehensive rebuilding and renovation programme began early in the year with commencement of a new building for the Mining and Engineering Departments and the work was well advanced by the end of the year.

Funds for this programme which is estimated to cost approximately $1,000,000 are being provided by the State Government with assistance from the Commonwealth Government which in October 1966 passed the States Grants (Advanced Education) Act 1966 embodying financial assistance for tertiary education throughout Australia.

Under this Act and subject to State expenditure on a $ for $ basis grants totalling $320,500 were made to the School for capital expenditure on buildings and equipment plus a maximum of $79,950 towards recurrent expenditure over the next three years.

The School continued to provide the usual services to industry and to the public in addition to its teaching activities. Samples submitted for assay or mineral determination increased from 442 in 1965 to 1,183 in 1966 and reflected the upsurge in prospecting activity particularly for nickel in the eastern goldfields.

(b) *Norseman.*

The 1964 and 1965 downward trend of enrolments at Norseman stopped in 1966 when the number of students increased by one to 51.

Two Reg Dowson Scholarships were awarded in 1966 and the 1965 winners of these Scholarships completed a fair year's work.

The good condition of the School buildings was further improved by some internal painting.

PART 5—INSPECTION OF MACHINERY.

The work of this Branch continued to increase in line with the general expansion of industry in Western Australia.

Boiler registrations rose by 474 to a total of 9,696 in 1966 as compared with the previous year and machinery groups registered increased from 52,479 in 1965 to 54,162 this year. The latter figures included 725 lifts in operation as compared with 681 at the end of 1965.

Inspectors carried out 6,656 boiler inspections and 34,824 machinery inspections during the year as compared with 6,739 and 30,441 respectively in 1965.

The Board of Examiners again dealt with an increasing number of applications and in 1966 granted Certificates of Competency to 136 Engine Drivers, 474 Crane Drivers and 107 Boiler Attendants. The corresponding figures for 1965 were 114, 336 and 68 respectively.

PART 6—GOVERNMENT CHEMICAL LABORATORIES.

Extensions to the buildings provided more space for personnel and equipment at the Laboratories and the staff was increased by 20% in 1966 to cope with the accumulation of samples to be examined and to meet increasing demands on the services available at this institution.

During the year 15,522 samples were received compared with 14,816 in 1965, and over the past five years the number of samples has increased by 45% from 10,658 in 1962.

In addition to dealing with the samples which come in from the State and Commonwealth Departments, Boards and Authorities as well as from the general public, the staff of the Laboratories also continued to serve on numerous committees, attend Courts when necessary and carry out advisory work as required.

The scope of the Laboratories is well indicated by the names of the Divisions:—

1. Agriculture and Water Supply Division.
2. Engineering Chemistry Division.
3. Food, Drugs, Toxicology and Industrial Hygiene Division.
4. Fuel Technology Division.
5. Industrial Chemistry Division.
6. Mineralogy, Mineral Technology and Geo-Chemistry Division.

In addition to the above Divisions there is also a Physics and Pyrometry Section and the wide range of subjects dealt with by the Laboratories is illustrated in the tremendous variety of samples shown in the detailed tables contained in Division VII of this Report.

PART 7—EXPLOSIVES BRANCH.

This branch continued to carry out its fundamental function of ensuring that explosives complied with State requirements and inspected all incoming shipments and railages of these materials.

The increasing wide-spread use of explosives, particularly those for geoseismic and underwater surveys, was illustrated by the interest shown in explosives landing, handling and storage facilities at most ports from Esperance to Wyndham.

To meet additional storage demands new explosives reserves were established during the year at Port Hedland and Geraldton, and the magazine sites at Woodman's Point were re-allocated.

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

Examination of mine-workers for silicosis and asbestosis detection continued during the year at the State X-ray Laboratory in Kalgoorlie and through the mobile X-ray unit which visited twelve gold and mineral fields.

A total of 6,847 examinations were made—59 more than in the previous year.

Compensation payments under the superseded Miners Phthisis Act scheme continued to decrease and amounted to $14,654 as compared with $15,676 during 1965. At the end of the year there were 65 beneficiaries receiving payments.

PART 9—SURVEY EXAMINATION AND DRAFTING BRANCH.

Surveys of mining tenements again rose steeply to a total of 478 as compared with an average of 177 during the past three years and the cost of contract surveys for 1966 was $62,525 as against $22,832 in 1965.

A new State Map based on Albers Projection was compiled and the printing of a further four 1:250,000 map sheets was finalised.

The branch continued to provide technical plans for the Geological Survey and general plans for the public, and charted 1,872 mining and oil tenement applications during the year.

PART 10—STAFF.

In keeping with Departmental tradition members of the staff responded with loyalty and efficiency to the challenge of the many problems and pressure of work which always accompany a mining 'boom' and I desire to express my sincere appreciation of their efforts.

In this summary of the various activities of the Department I have mentioned only the main items. Detailed reports of the Branch Sub-heads are contained in Divisions II to X hereunder.

I. R. BERRY,
Under Secretary for Mines.

Department of Mines, Perth.

DIVISION II

Report of the State Mining Engineer for the Year 1966

Under Secretary for Mines:

I submit for the information of the Honourable Minister for Mines the annual report of the State Mining Engineer's Branch.

Mining activities for the year 1966 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.

There were no staff changes during the year.

ACCIDENTS.

Fatal and serious mining accidents reported to the Department are shown below. The corresponding figures for 1965 are shown in brackets.

There were 11 (11) fatal and 372 (410) serious accidents.

In gold mines there were 6 (6) fatal and 228 (257) serious accidents. The number of men employed in such mines was 4,411 (4,468). The accident rate per 1,000 men was thus 1.36 (1.34) for fatal accidents and 51.69 (57.52) for serious accidents.

Fatal accidents in other mines included rock quarries 2, nickel 1, iron ore 1, and oil exploration 1.

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

TABLE A

Serious Accidents for 1966

Class of Accident	West Kimberley	Kimberley	Pilbara	West Pilbara	Ashburton	Peak Hill	Gascoyne	Murchison	North Coolgardie	East Coolgardie	Coolgardie	Dundas	Phillips River	South West	Collie	Total
Major Injuries—Exclusive of Fatal—																
Fractures—																
Head	....	....	....	....	....	....	....	....	....	1	....	....	....	....	....	1
Shoulder	....	....	....	....	....	....	....	....	....	1	....	....	....	....	....	1
Arm	....	....	....	....	....	....	....	....	....	1	....	....	....	....	....	1
Hand	....	....	....	....	....	....	....	....	....	4	....	....	....	....	....	4
Spine	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Rib	1	....	....	....	1	....	....	....	....	1	....	....	....	....	....	3
Pelvis	....	....	....	....	....	....	....	....	....	1	....	....	....	....	....	1
Thigh	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Leg	1	....	....	2	....	....	....	....	....	3	....	....	....	....	....	6
Ankle	....	....	....	....	....	....	....	....	....	....	....	....	....	....	2	2
Foot	....	....	....	....	....	....	....	....	....	5	....	....	....	1	....	6
Amputations—																
Arm	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Hand	....	....	....	....	....	....	....	....	....	1	....	....	....	....	....	1
Finger	....	....	....	....	....	1	....	1	....	1	....	....	....	2	2	7
Leg	....	....	....	1	....	....	....	....	....	....	....	....	....	....	....	1
Foot	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Toe	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Loss of Eye	....	....	....	1	....	....	....	....	....	....	....	....	....	....	....	1
Serious Internal	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Hernia	....	....	....	....	....	....	....	....	....	2	....	....	1	3	2	8
Dislocations	....	....	....	....	....	....	....	....	....	2	....	1	....	....	....	3
Other Major	....	....	....	....	....	....	....	....	....	2	....	....	....	....	....	2
Total Major	2	....	....	4	1	1	....	1	....	25	....	1	1	6	6	48
Minor Injuries—																
Fractures—																
Finger	1	....	....	2	1	....	....	....	....	8	....	1	....	2	1	16
Toe	....	....	....	....	....	....	....	....	....	2	....	1	....	1	1	5
Head	....	....	....	1	2	....	....	....	....	2	....	1	....	1	....	7
Eyes	....	....	....	....	....	....	....	2	1	12	....	3	....	1	2	21
Shoulder	....	....	....	....	....	....	....	....	....	5	....	....	....	2	2	9
Arm	1	....	....	....	....	....	....	1	....	9	....	....	1	2	....	14
Hand	....	1	3	1	9	....	2	2	....	50	1	5	....	9	3	86
Back	....	1	1	3	1	1	....	1	2	33	1	2	....	6	13	65
Rib	....	....	....	....	....	....	....	....	....	3	....	....	....	....	....	3
Leg	3	....	2	3	3	....	....	1	....	31	....	4	2	6	3	58
Foot	....	....	....	2	1	....	....	....	....	19	....	1	....	6	1	30
Other Minor	....	....	....	1	....	....	....	....	1	2	....	....	1	1	4	10
Total Minor	5	2	6	13	17	1	2	7	4	176	2	18	4	37	30	324
Grand Total	7	2	6	17	18	2	2	8	4	201	2	19	5	43	36	372

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

Yalgoo, North-East Coolgardie, Broad Arrow, Mount Margaret, Yilgarn, East Murchison, Greenbushes, Northampton.

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	342	....	13	23
Bauxite	376	....	13	15
Coal	726	....	36	265
Copper	99	....	6	34
Gold	4,411	6	228	1,003
Gypsum	13	....	....	....
Ilmenite	322	....	7	52
Iron Ore	562	1	22	92
Lead	27	....	....	....
Manganese	35	....	1	3
Nickel	60	1	2	1
Oil Exploration	432	1	40	56
Pyrite	102	....	4	37
Tin	222	....	....	4
Other Minerals	71	....	....	....
Rock Quarries	240	2	....	....
Totals	8,040	11	372	1,585

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	....	....	....	....	....	....	....	....	....	....	....	2	....	2
West Kimberley	....	....	....	....	....	....	....	....	....	2	....	5	....	7
Pilbara	....	....	....	....	....	....	....	....	....	....	....	6	....	6
West Pilbara	....	....	....	....	....	....	....	....	....	11	1	6	1	17
Ashburton	....	....	....	....	....	....	....	....	....	....	1	18	1	18
Peak Hill	....	....	....	....	....	....	....	....	....	....	....	2	....	2
Gascoyne	....	....	....	....	....	....	....	....	....	....	....	2	....	2
Murchison	....	....	....	1	....	....	....	....	....	5	1	2	1	8
East Murchison	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Yalgoo	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Northampton	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Mount Margaret	....	....	....	....	....	....	....	....	....	....	....	....	....	....
North Coolgardie	....	....	....	....	....	....	....	....	....	4	....	....	....	4
Broad Arrow	....	....	....	....	....	....	....	....	....	....	....	....	....	....
North-East Coolgardie	....	....	....	....	....	....	....	....	....	....	....	....	....	....
East Coolgardie	....	3	1	26	....	5	....	....	2	136	....	31	3	201
Coolgardie	....	....	....	....	1	2	....	....	....	....	....	....	1	2
Yilgarn	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Dundas	....	....	1	1	1	3	....	....	....	10	....	5	2	19
Phillips River	....	....	....	....	....	....	....	....	....	5	....	....	....	5
Greenbushes	....	....	....	....	....	....	....	....	....	....	....	....	....	....
South-West	....	....	....	....	....	....	....	....	1	4	1	39	2	43
Collie	....	....	....	1	....	....	....	....	....	29	....	6	....	36
Total for 1966	....	3	2	29	2	10	....	....	3	206	4	124	11	372
Total for 1965	....	2	2	23	2	6	1	....	3	246	3	133	11	410

FATAL ACCIDENTS

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

Name and Occupation	Date	Mine	Details and Remarks
Scott, Frank Muir (Mine Owner)	21/1/66 Died 22/1/66	Blue Bird G.M.L. 1853N, Yaloginda	Died from injuries received when he drove a front end loader over the edge of a 28 ft. deep section of the open cut.
Pudler, Frederick Gerhard (Rigger)	28/1/66	Mt. Tom Price Hamersley Iron Pty. Ltd.	Crushed when the unsupported jib of a crane collapsed during dismantling operations.
Vitale, Damiano (Quarryman)....	25/3/66	Limestone Quarry M.C. 1093H, Wanneroo	Vitale was engaged in cutting building stone when he was struck by a broken section from a nearby stone.
O'Meara, Gerald Walter Patrick (Winder Driver)	6/6/66	North Royal Internal Shaft, Central Norseman Gold Corp. N.L., Norseman	He was ascending the underlay shaft in a skip when his head struck a roller which was fixed at a bend about 100 ft. below the No. 13 level.
Hall, Clarence Robert Lester (Timberman)	15/6/66	Chaffers Shaft, Lake View and Star Ltd., Fimiston	Hall and another timberman were engaged in cutting hitches on the 1,400 ft. int. level Hannans Star West Lode when a slab of rock fell from the wall and pinned them. He was drowned when his face was forced into a shallow pool of water which had accumulated during the boring operations.
Browder, William James (Driller's Assistant)	17/6/66	Barrow Island, Oil Drilling & Exploration (W.A.) Pty. Ltd. contractor to West Australian Petroleum Pty. Ltd.	Browder died from injuries received when he was struck by a falling travelling block. The drilling line broke when the travelling block was overwound into the crown block.
Bielawski, Stanislaw (Machine Miner)	24/8/66	Regent Shaft, Central Norseman Gold Corporation N.L., Norseman	Struck by a slab of rock which fell from the hanging wall of the 23/36 stope above the No. 23 level.
Marks, Ernest Clarence (Quarry Superintendent)	29/10/66	Rock Quarry 3 miles east of Merredin. Thiess Bros. Pty. Ltd.	The deceased was crushed when a front end loader he was driving overturned. Apparently the machine was being driven with the loaded bucket in a raised position and one wheel mounted a 3 ft. high rock heap.
Holtzman, Victor Richard (Ore Checker)	17/11/66	Main Shaft, Great Boulder Gold Mines Ltd., Fimiston	Suffered multiple injuries when he lost his balance and fell 140 ft. down the 28H ore pass on the 1,750 ft. level. At the time of the accident he was engaged in running ore through from the 1,600 ft. level pass.
Barlow, Stanley (Sampler)	28/11/66	Chaffers Shaft, Lake View and Star Ltd., Fimiston	It would appear that Barlow was buried by a run of ore in the 1,500 ft. level Hannans Star West Lode shrink stope.
Rymer, Brian Desmond (Miner—Shaft Sinking)	28/12/66	Kambalda No. 1 shaft, Western Mining Corporation Ltd., Kalgoorlie	Rymer was assisting in installing shaft timbers at the No. 4 level when a section of the framework was dislodged from its seating. The sudden movement caused him to lose his balance and he fell 33 ft. to the bottom of the shaft.

WINDING MACHINERY ACCIDENTS.

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

Fatal—(1). This accident in the North Royal Internal Shaft appears under Fatal Accidents in this report.

Overwinds—(2). On the 12th May an overwind occurred when a winder driver, newly employed, was familiarising himself with the winder on the North Royal shaft, Central Noresman Gold Corporation N.L. The north side skip was empty at the tipping position and the south skip full at the 900 feet level. When the signal "to hoist" was given the driver applied power and released the brake but unfortunately he had the controller in the wrong direction and the north skip was wound up to the sheave. Both the skip and the sheave were replaced.

An overwind occurred at the Timoni gold mine Mt. Ida on the 29th August when the skip apparently entered the dumping track faster than normal and overtravelled. The speed was sufficiently low enough for the driver to stop the skip before the detaching hook fully entered the thimble. The partially closed detaching hook sheared the copper rivet but did not release the rope.

Skip Hung Up—(1). An unusual accident occurred in the Croesus Shaft, North Kalgurli (1912) Ltd. on the 1st August when ore was being hoisted. One skip was tipping at the surface bin when a rock became jammed. When the rock was freed, it fell down the shaft and struck the attachments of the other skip which was at a loading position. The impact severed the copper safety rivet of the detaching hook and the rope was detached from the skip. The rock also splintered a skid and bent the hood of the skip. The skip was suspended by the grippers.

Derailments—(3). When a skip with mancar attached was being run through the North Royal Shaft, Central Norseman Gold Corporation N.L., prior to lowering the men on the 27th July both the skip and mancar were derailed 20 feet below the 1,000 level. No damage was reported.

Central Norseman Gold Corporation N.L. reported two derailments in the Regent shaft. On the 14th October a skip loaded with mullock was being pulled away from the No. 29 level bin when it was derailed by spillage. Two centre legs were knocked out. On the 25th November a skip was derailed near the No. 22 level bin whilst the skipman was cleaning down the shaft. There was no damage.

Mechanical Failure—(3). Whilst ore was being hoisted in the north compartment of the Ivanhoe shaft, Lake View and Star Ltd. on the 13th May, one cheek of the head sheave broke away. Inspection revealed that the occurrence resulted from normal wear. The rope remained in the sheave and suffered no damage.

The 8 in. x 6 in. Karri timber beam carrying the upper pulley block failed when the Cryderman mucker anchor was being lowered in the Kambalda shaft, Western Mining Corporation N.L. on the 10th September. Although it was found that the beam was composed of short length fibre it was considered that the hoist operator was too severe with the brakes. Steel sections replaced the timber, At the Lake View and Star Ltd., Lake View shaft on the 2nd December it was noted that the centre drum shaft bearing of the winder was excessively hot. Inspection revealed three cracks in the drum shaft which was replaced.

Miscellaneous—(4). The failure of a platman to securely close and secure the gate of the cage, in the Mt. Charlotte shaft on the 24th June, allowed equipment being hoisted to foul the shaft timber. The cage was later replaced.

On the 29th August at the 1,300 feet level plat Perseverance shaft the cage was hoisted with the cage door swinging outwards. Before the cage could be stopped the door caught on the plat set and was broken off. In addition, one chain on the gripper gear was stretched. This accident resulted from the incorrect number of rings being given on the signalling system or a misunderstanding of the actual rings received. The platman reported ringing 5 and the driver claimed 4 only were received.

The gate was broken from the cage in the Perseverance shaft on the 21st October, when the platman forgot to close it. The gate caught on the plat cap and injured a skipman who received chest and knee injuries.

On the 20th December at the New North Boulder shaft a new cage left a skid at a depth of 412 ft. The grippers on the other side operated and suspended the cage which contained five men. No injuries or damage resulted from this accident but the cage was replaced as it was too narrow for the shaft.

PROSECUTIONS.

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

One man was prosecuted for failing to use the ventilation equipment provided in a development heading off the Main Shaft, North Kalgurli (1912) Ltd.

A miner was prosecuted for firing outside the prescribed times in a stope off Invanhoe Shaft, Lake View and Star Ltd.

Two winzemen were prosecuted for failing to use water provided to suppress dust while boring in a winze off the Oroya shaft, Gold Mines of Kalgoorlie (Aust.) Ltd.

SUNDAY LABOUR PERMITS

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

Permission was given, to Great Boulder Gold Mines Ltd., to transport ore underground and hoist it up Hamilton Shaft on one Sunday. The Edwards shaft winder was out of action and the permit was granted to maintain ore supplies to the mill.

Four permits were issued to Gold Mines of Kalgoorlie (Aust.) Ltd. to employ labour on four Sundays in the Mount Charlotte mine. The permits covered construction of a ventilation rise (2), construction of a loading station and ore pocket in close proximity to the shaft, and to remove the pentice from the shaft.

Central Norseman Gold Corporation N.L. was issued with two permits for the commencement of a crosscut off No. 19 level Regent shaft, and for the construction of a transformer chamber on the same level.

Ravensthorpe Copper Mines N.L. received permission to work on two Sundays to remove a rock pentice and to install shaft timbers in the Elverdton shaft.

Four permits, each of three months duration, were issued to Western Titanium. The permits were granted so that the company could increase output during a period of increased sales of ilmenite and while equipment was being installed.

Western Mineral Sands Pty. Ltd. received permission to work in the pit on seven Sundays during a period when mining low grade material. This allowed the company to maintain sufficient heavy material concentrate feed to the separation plant working a five day week.

AUTHORISED MINE SURVEYORS

The Survey Board issued one certificate during the year.

CERTIFICATES OF EXEMPTION (SECTION 46).

No certificates were issued during 1966.

PERMITS TO FIRE OUTSIDE PRESCRIBED TIMES (REGULATION 51).

Four permits were issued.

PERMITS TO RISE (REGULATION 64).

Forty permits were issued for the construction of 92 rises totalling 11,104 feet. Seventy four of these rises were advanced using the rising gig method.

ADMINISTATIVE

Mines Regulation Act—Regulation 14 was amended (Government Gazette No. 16 of 10th February) following a review of wages payable to Workmen's Inspectors of Mines.

The Gascoyne Goldfield was proclaimed a Mining District. This notice appeared in the Government Gazette No. 21 dated 25th February.

The Government Gazette No. 16 of the 10th February included a general amendment of monetary references and an amendment to regulation 21 covering fees payable to returning officers at Workmen's Inspectors elections.

Coal Mines Regulation Act—Conversion to decimal currency was covered by a notice appearing in the Government Gazette dated 10th February.

No amendments were made to the Mining Act, and the Mine Workers' Relief Act during the year under review.

VENTILATION

All mines throughout the State were inspected during 1966. Air flow, dust counts and temperatures were recorded at all working places. Inspection of crushing and screening installations included metalliferous and asbestos treatment plants, rock quarries, iron ore quarries and dry treatment plants associated with the heavy mineral sands industry.

The testing of toxic fumes and vapours associated with the various assay laboratories and reduction plants was continued. Regularly throughout the year undiluted exhaust gases, from diesel powered equipment in use underground at the Mt. Charlotte mine, were sampled and gas concentrations determined. All concentrations of the various gases recorded for both diluted mine air samples and undiluted exhaust gases have been well below the maximum allowable concentrations permitted. The average airflow was 88,000 cubic feet per minute through the main working stope where the diesel equipment was operating.

Sixteen reports of methane in metalliferous mines were received during the year. North Kalgurli (1912) Ltd. reported eleven occurences, Great Boulder Gold Mines Ltd. 2, and Hill 50 Gold Mine N.L., 3. Most of these occurences were weak flows intersected by diamond drill holes. The gas was also detected during normal development work on the No. 12 level Croesus shaft where the miner was boring solid calc schist in the drive face. The three occurrences of gas reported at Hill 50 were intersected below the 3010 feet level in two drill holes and in a winze in the same area. No methane was detected in the underground workings of the Collie coal mines.

During the year the total number of dust samples recorded both surface and underground was 1,494 at an average of 362 p.p.c.c. This was a slight increase compared with 1965 results when 1,226 samples averaged 349 p.p.c.c. The increased average dust count can be attributed to the increase in the number of samples obtained from the various crushing operations where dust control is inadequate.

Results of dust counts taken during the year are tabulated below. Corresponding figures for 1965 are shown in brackets.

Dust Samples from	Samples Giving Over 1,000 p.p.c.c.	Total Number of Samples	Average Count
Development	2 (4)	213 (169)	235 (298)
Stoping	26 (23)	647 (556)	309 (312)
Levels	25 (24)	293 (262)	342 (352)
Surface	76 (45)	341 (239)	560 (468)
Totals	129 (96)	1,494 (1,226)	362 (349)

It is with pleasure that I report that for the tenth year in succession there has not been a fatal accident due to fumes of explosives. Thirteen alleged fuming accidents were reported and all were investigated. Five cases of fuming were lost time accidents caused by men returning to their working places too soon after firing.

In conjunction with the Department of Public Health urine samples were obtained from men employed in the lead mining industry and in assay laboratories. Two men of the seventy six examined showed symptoms of mild lead poisoning. Both men were employed in an assay laboratory.

Aluminium Therapy—The prophylactic treatment with aluminium powder was continued at all gold mines. Both management and labour show little interest in this treatment for the prevention of silicosis.

GROUND VIBRATION

Six projects, where explosives were used in close proximity to structures which could suffer damage from excessive vibration, were checked using the Department's Sprengnether seismograph. This three component 100 magnification instrument was used in tests to assist other Departments and industry within the State. Seismograms were obtained from underwater blasting in the Geraldton harbour, City Beach and in Cockburn Sound as well as quarrying operations at Jarrahdale, Koolanooka and Carnamah. Vibrations, from diesel equipment used on the standard guage railway, were measured at Midvale, Toodyay and Spearwood.

GOLD MINING

The ore treated during the year amounted to 2,619,016 tons as compared with 2,530,165 tons in the previous year. Gold recovered amounted to 627,052 fine ounces as compared with 656,355 fine ounces for 1965.

Grade of ore mined was lower, recovery being 4.79 dwts. per ton as against 5.19 dwts. per ton for 1965.

The calculated value of the gold produced was $19,702,406 which included $107,031 distributed by the Gold Producers' Association from the sale of 806,253 fine ounces of gold at an average premium of 14.39 cents per fine ounce.

The Mint value of gold throughout the year was $31.25 per fine ounce.

There was a decrease in the number of men employed in the industry from 4,468 in 1965 to 4,411 in 1966. This decline was brought about by the general shortage of labour available notwithstanding efforts made to recruit labour from overseas. Average production of ore per man was 594 tons valued at $7.523 per ton as compared with 566 tons valued at $8.150 per ton for 1965. Gold recovery per man averaged 142.16 fine ounces as compared with 146.90 fine ounces for the previous year.

Statistics relating to the gold mining industry are tabulated as follows.

Table "D"—Gold Production Statistics.

Table "E"—Classification of Gold Output for 1966 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	$A		$A	Dwts.
1937	3,039,608	1,007,289	17,595,324	5.799	16,174	17.468	6·64
1938	3,759,720	1,172,950	20,819,856	5.338	15,374	17.750	6·24
1939	4,095,257	1,188,286	23,188,442	5.662	15,216	19.514	5·80
1940	4,291,709	1,154,843	24,613,632	5.735	14,594	21.315	5·38
1941	4,210,774	1,105,477	23,623,978	5.610	13,105	21.370	5·25
1942	3,225,704	845,772	17,681,284	5.481	8,123	20.904	5·24
1943	2,051,011	531,747	11,113,472	5.419	5,079	20.900	5·19
1944	1,777,128	472,588	11,932,902	5.589	4,614	21.018	5·32
1945	1,736,952	469,906	10,050,078	5.786	4,818	21.387	5·41
1946	2,194,477	618,607	13,315,524	6.070	6,961	21.525	5·64
1947	2,507,306	701,752	15,105,222	6.025	7,649	21.525	5.59
1948	2,447,545	662,714	14,265,496	5.828	7,178	21.525	5·42
1949	2,468,297	649,572	15,954,400	6.464	6,800	24.562	5·26
1950	2,463,423	608,633	18,857,490	7.655	7,080	30.983	4·94
1951	2,471,679	648,245	20,084,784	8.126	6,766	30.983	5·25
1952	2,626,612	727,468	23,618,094	8.992	6,394	32.466	5·54
1953	3,169,875	823,331	26,580,200	8.385	6,359	32.284	5·20
1954	3,240,378	861,992	26,984,418	8.327	6,128	31.304	5·32
1955	2,865,048	834,326	26,111,148	9.113	5,845	31.296	5·82
1956	2,870,273	813,617	25,449,846	8.867	5,612	31.280	5·67
1957	2,951,011	849,741	26,609,504	9.017	5,385	31.315	5·76
1958	3,021,072	874,819	27,348,386	9.053	5,352	31.262	5·79
1959	2,959,202	860,969	26,907,616	9.093	5,769	31.252	5·82
1960	3,056,445	869,966	27,186,924	8.895	5,430	31.251	5·69
1961	2,984,458	870,658	27,369,734	9.171	5,337	31.436	5·83
1962	2,989,653	860,039	26,889,722	9.010	5,353	31.266	5·75
1963	2,770,166	802,860	25,114,068	9.066	5,297	31.281	5·80
1964	2,645,956	715,481	22,382,200	8.459	4,785	31.283	5·41
1965	2,530,165	656,355	20,621,258	8.150	4,468	31.418	5·19
1966	2,619,016	627,052	19,702,406	7.523	4,411	31.421	4·79

TABLE E

Classification of Gold Output for 1966 by Goldfields

Goldfields	Unclassified Sundry Claims, Alluvial, etc.	Up to 500 ozs.		501–1,000 ozs.		1,001–10,000 ozs.		10,001–50,000 ozs.		Over 50,000 ozs.		Total
		No. of Producers	Gold	No. of Producers	Gold	No. of Producers	Gold	No. of Producers	Gold	No. of Producers	Gold	
	fine oz.		fine oz.		fine oz.		fine oz.		fine oz.		fine oz.	fine oz.
Kimberley	8	1	10	....	....	....	....	....	....	....	....	18
West Kimberley	....	....	....	....	....	....	....	....	....	....	....	....
Pilbara	118	6	132	1	667	....	....	....	....	....	....	917
West Pilbara	....	....	....	....	....	....	....	....	....	....	....	....
Ashburton	....	....	....	....	....	....	....	....	....	....	....	....
Peak Hill	....	1	6	....	....	....	....	....	....	....	....	6
Gascoyne	....	1	350	....	....	....	....	....	....	....	....	350
Murchison....	756	7	515	....	....	....	....	1	41,201	....	....	42,472
East Murchison	111	5	425	1	508	....	....	....	....	....	....	1,044
Yalgoo	7	....	....	....	....	....	....	....	....	....	....	7
Mount Margaret	353	4	362	....	....	....	....	....	....	....	....	715
North Coolgardie	204	10	435	....	....	1	9,697	....	....	....	....	10,336
Broad Arrow	1,053	13	1,222	....	....	....	....	....	....	....	....	2,275
North-East Coolgardie	150	3	337	....	....	....	....	....	....	....	....	487
East Coolgardie	678	17	1,083	....	....	....	....	....	....	4	459,503	461,264
Coolgardie	3,171	16	1,099	....	....	1	1,366	....	....	....	....	5,636
Yilgarn	404	6	616	....	....	....	....	....	....	....	....	1,020
Dundas	136	1	5	....	....	....	....	....	....	1	98,922	99,063
Phillips River	....	....	....	....	....	1	1,389	....	....	....	....	1,389
South-West	....	....	....	....	....	....	....	....	....	....	....	....
State Generally	53	....	....	....	....	....	....	....	....	....	....	53
Totals	7,202	91	6,597	2	1,175	3	12,452	1	41,201	5	558,425	627,052
Production, 1965	4,865	83	5,471	5	3,425	3	4,817	1	12,987	6	624,790	656,355
Production, 1964	6,572	117	8,812	3	2,309	6	9,054	2	30,602	6	658,132	715,481
Production, 1963	5,651	108	6,392	2	1,207	8	27,136	3	61,136	6	701,338	802,860
Production, 1962	5,712	100	6,788	4	3,180	7	23,434	2	39,655	7	781,270	860,039

TABLE F

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

Mine	1966			1965			1964			1963			1962		
	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.	188,647	98,922	10·49	182,589	95,114	10.42	181,814	100,340	11·04	189,248	102,702	10·85	181,834	109,506	12·04
Eclipse Gold Mines N.L.	....	....	....	....	....	....	....	....	....	4,449	4,567	20·53	6,086	6,757	22·21
Gold Mines of Kalgoorlie (Aust.) Ltd.	849,953	158,136	3·72	743,364	155,057	4.17	704,369	146,366	4·16	527,680	141,837	5·38	518,747	140,919	5·43
Great Boulder Gold Mines Ltd.	360,417	83,129	4·61	387,894	92,347	4.76	425,292	111,415	5·24	450,249	118,520	5·26	450,192	121,628	5·40
Great Western Consolidated N.L.	....	....	....	....	....	....	....	....	....	124,062	15,159	2·44	390,462	61,352	3·14
Hill 50 Gold Mines N.L.	156,859	41,201	5·25	164,671	54,232	6.59	185,232	69,553	7·51	162,558	78,196	9·62	165,698	87,196	10·52
Lake View and Star Ltd.	644,625	148,130	4·60	619,672	151,997	4.91	683,488	164,387	4·81	690,537	168,170	4·87	694,054	172,001	4·96
North Kalgurli (1912) Ltd.	364,140	70,108	3·85	364,561	76,043	4.17	379,630	82,602	4·35	371,967	85,908	4·62	368,350	84,559	4·59
State Batteries	29,422	12,932	8·79	41,481	12,660	6·10	43,967	12,521	5·70	43,944	13,236	6·02	48,154	13,697	5·69
The Sons of Gwalia Ltd.	....	....	....	....	....	....	....	....	....	159,651	31,344	3·93	121,773	25,950	4·26
Timoni (Moonlight) Wiluna G.M. Ltd.	24,910	9,697	7·79	25,338	12,987	10.25	29,353	14,386	9·80	28,914	14,633	10·12	24,493	13,705	11·19
Totals	2,618,973	622,255	4·75	2,529,570	650,437	5.14	2,633,145	701,570	5·33	2,753,259	774,272	5·62	2,969,843	837,270	5·64
Other Sources (excluding large Retreatment Plants)	43	2,432	1,131·16	595	3,451	116.00	12,811	10,263	16·02	16,907	17,106	20·24	19,810	10,841	10·94
Totals (excluding large Retreatment Plants)	2,619,016	624,687	4·77	2,530,165	653,888	5.17	2,645,956	711,833	5·36	2,770,166	791,378	5·71	2,989,653	848,111	5·67
Lake View and Star Retreatment	....	....	....	....	....	....	....	1,048	....	....	9,222	....	....	9,094	....
State Batteries Tailings Treatment	....	2,365	....	....	2,467	....	....	2,600	....	....	2,260	....	....	2,834	....
Grand Totals	2,619,016	627,052	4·79	2,530,165	656,355	5.19	2,645,956	715,481	5·41	2,770,166	802,860	5·80	2,989,653	860,039	5·75

TABLE G

Development Footages Reported by the Principal Mines

Gold or Mineral Field	Mine	Shaft Sinking	Driving	Cross Cutting	Rising and Winzing	Exploratory Drilling	Total
		feet	feet	feet	feet	feet	feet
Gold—							
Murchison	Hill 50 Gold Mine N.L.	42	3,062	1,248	1,032	7,780	13,164
North Coolgardie	Timoni (Moonlight Wiluna G.M. Ltd.)	....	553	53	280	1,510	2,396
East Coolgardie	Lake View and Star Ltd.	....	19,931	2,742	3,527	27,422	53,622
	Great Boulder Gold Mines Ltd.	478	6,537	567	1,971	8,739	18,292
	North Kalgurli (1912) Ltd.	301	12,780	1,339	2,512	32,457	49,389
	Gold Mines of Kalgoorlie (Aust.) Ltd.	155	18,028	6,725	8,592	34,566	68,066
	Daisy	....	156	132	92	....	380
Dundas	Central Norseman Gold Corporation N.L.	....	2,237	2,630	2,064	47,855	54,786
	Total in Gold Mines	976	63,284	15,436	20,070	160,329	260,095
Asbestos—							
West Pilbara	Australian Blue Asbestos Pty. Ltd.	....	706	....	....	3,505	4,211
Pyrite—							
Dundas	Norseman Gold Mines N.L.	....	250	67	277	....	594
Copper—							
Phillips River	Ravensthorpe Copper Mines N.L.	44	718	337	242	124	1,465
West Pilbara	Westfield Minerals (W.A.) N.L.	....	70	....	....	18,910	18,980
Peak Hill	Thaduna Copper Mining Coy. Pty. Ltd.	....	....	....	....	2,901	2,901
	Total in Copper Mines	44	788	337	242	21,935	23,346
Lead—							
Northampton	Mary Springs Lead Mine	....	150	....	....	4,191	4,341
Nickel—							
Coolgardie	Western Mining Corporation Ltd.	425	....	....	111	32,372	32,908
Iron—							
Yalgoo	Iron Hill Pty. Ltd.	....	....	1,090	....	2,494	3,584
West Pilbara	Mount Newman Iron Ore Co. Ltd.	....	....	....	....	3,446	3,446
Pilbara	Goldsworthy Mining Limited	....	....	....	....	660	660
	Total in Iron Mines	....	....	1,090	....	6,600	7,690
	Total in All Mines	1,445	65,178	16,930	20,700	228,932	333,185

OPERATIONS OF THE PRINCIPAL MINES.

EAST COOLGARDIE GOLDFIELD.

The total ore treated in this goldfield amounted to 2,221,616 tons with a recovery of 461,264 fine ounces of gold at an average of 4.15 dwts. per ton. This output was equal to 73.6 per cent of the gold production for the State. In the previous year 2,121,278 tons of ore averaging 4.51 dwts. were treated for a recovery of 477,900 fine ounces of gold.

Production in the *Bulong District* amounted to 143 fine ounces from the treatment of 154 tons of ore.

In the *East Coolgardie District* 461,121 fine ounces were recovered from the treatment of 2,221,462 tons of ore. Following are notes on the activities of the principal producers in the district.

Gold Mines of Kalgoorlie (Aust.) Ltd. with a production of 849,953 tons of ore for a return of 158,136 fine ounces of gold at an average recovery of 3.72 dwts. per ton was the State's leading producer. Production from the Fimiston leases was 468,779 tons yielding 107,789 ounces and from Mount Charlotte 381,174 tons yielding 50,347 ounces. In addition, tributers working in the Coolgardie area obtained 177 ounces from the treatment of 651 tons of ore.

Ore reserves at the 28th June were 5,554,000 tons at 3.8 dwts. per ton which included 881,000 tons of refractory ore from the Fimiston leases averaging 5.2 dwts. and 4,673,000 tons of 3.5 dwts. free milling ore, mainly at Mount Charlotte. About one million tons of the Mount Charlotte reserves will be left unbroken in pillars.

Placement of dry fill in old workings in the Oroya section was continued but in the Perseverance-South Kalgurli this operation has been stopped. Cut and fill mining provided 46% of stope ore mined at Fimiston and involved placing underground over 100,000 tons of hydraulic fill. Over one half of Fimiston development was on the complex lode systems of the upper levels of the Perseverance and South Kalgurli leases. The Federal lode, down to No. 11 level, again provided most development targets on the Paringa. Preparations have been made for mining in the vicinity of the Hinchcliffe shaft which was re-opened to the No. 3 level.

Work continued on the development of the No. 9 level at Mount Charlotte. A start has been made on the sinking of a man and supply shaft. The 50 H.P. electric winder installed on No. 5 level for sinking Reward shaft was re-installed on No. 9 level where a pumping station, temporary loading station and electric sub-station have been established. The loading station at the 1,050 horizon was completed. The six diesel units, operating in workings off the Reward shaft, continued to give good service under satisfactory ventilation and operating conditions. Average air flow through the dry sand and gravel filled stope was 88,000 cubic feet per minute.

Total development work undertaken by Gold Mines of Kalgoorlie during the year amounted to 68,066 feet made up of 155 feet of shaft sinking, 18,028 feet driving, 6,725 feet crosscutting, 8,592 feet rising and winzing and 34,566 feet of exploratory drilling.

Auriferous pyritic concentrates railed to fertilizer works in the metropolitan area contained, in addition to gold, 7,586 tons of sulphur.

Lake View and Star Ltd. produced 148,130 fine ounces of gold from the treatment of 644,625 tons of ore at an average recovery of 4.60 dwts. per ton. The previous year's production was 151,997 fine ounces from the treatment of 619,672 tons.

Estimated ore reserves as at the 1st July were 3,352,100 short tons at 4.72 dwts. per ton.

Development work completed during the year amounted to 26,200 feet. In addition 27,200 feet of exploratory drilling was undertaken.

The shortage of labour throughout the greater part of the year was eased somewhat by the company offering assistance by the way of interest free loans for home purchase. The migration scheme to recruit miners from the United Kingdom was continued and 58 men were engaged from this source during the year.

A new centrifugal pumping system was installed at the Lake View Shaft. This automatic system replaced the plunger pump which previously handled the water in the eastern group. The Lake View shaft, now 2,914 feet deep, has three T.C. 2/11 stage Pulsometer pumps operating on the 1,000, 1,900 and 2,820 feet levels.

The 19 and 20 levels of Associated shaft which have never been worked by Lake View and Star were opened up for development by dewatering and rehabilitating the shaft below the No. 18 level.

The enlargement of the post-cyanidation section of the treatment plant was completed with the installation of the last of three Brown agitators and a filter ex the Chaffers Retreatment plant. A Gemco-Funkey 10 ton diesel locomotive for surface transport was purchased.

Control and management of the company was transferred to Australia as from the 1st November. This previously United Kingdom based company now has its head quarters in Sydney, N.S.W.

Great Boulder Gold Mines Ltd. treated 360,417 tons of ore for a recovery of 83,129 fine ounces of gold at an average recovery of 4.61 dwts. per ton. During the previous year 387,894 tons yielded 92,347 fine ounces at an average recovery of 4.76 dwts. per ton.

Ore reserves at the 30th June were estimated to be 1,737,130 short tons averaging 4.78 dwts. per ton.

The Edwards shaft is currently being deepened to 4,100 feet. On completion of this work, ore haulage distances will be reduced and ore hoisting up the Main internal shaft will be eliminated. Ventilation throughout the mine particularly in the deeper levels will also be improved.

Development, totalling 9,553 feet, was widely distributed with most of this work concentrated on the 1,900, 2,350 and 2,650 feet levels of Edwards shaft. At Hamilton shaft the most successful development were on the 2,400 and 2,650 feet levels.

A significant increase in recovery of gold was obtained in the plant by finer grinding and more efficient agitation. Experimental work undertaken for the recovery of mercury and tellurium was successful in the laboratory. Plant is to be installed for the recovery of these metals.

The company has taken an option over the Knight Commander gold mining lease some 45 miles north west of Kalgoorlie. This area is to be mapped and diamond drilled to determine the potential of the sulphide zone.

North Kalgurli (1912) Ltd. treated 364,140 tons of ore for a recovery of 70,108 fine ounces of gold at an average recovery of 3.85 dwts. per ton. During the previous year 76,043 fine ounces were recovered from 364,561 tons of ore.

Development completed during the year included shaft sinking 301 feet, driving 12,780 feet, crosscutting 1,339 feet, winzing 1,549 feet, rising 963 feet, and exploratory drilling 32,457 feet. Sinking of the Main shaft was completed to 2,420 feet below the surface and a loading station constructed at 2,375 feet. It is anticipated that two new levels at 2,160 feet and 2,310 feet will be developed early in the new year.

The programme of constructing a series of rises between the No. 17 and No. 13 levels is nearly complete. On completion of this work, exhaust air will be directed to the Union Jack shaft where it will be exhausted to atmosphere. At present the Main shaft is upcasting and the Kalgurli shaft downcasting below the No. 4 level.

There was a further decline in mining at Mount Monger. The *Rosemary* with an output of 336 fine ounces from 499 tons is expected to cease operations shortly. Most of the ore was obtained from an underhand stope below the No. 3 level. The *Daisy* produced 151 fine ounces from 184 tons of ore. Ore reserves in this small high grade mine are estimated at 1,000 tons blocked out between the Nos. 8 and 9 levels.

DUNDAS GOLDFIELD.

The production of 99,063 fine ounces of gold from the treatment of 188,691 tons of ore represented 15.8 per cent of the State's total production. In the previous year 182,714 tons of ore yielded 95,393 fine ounces.

Central Norseman Gold Corporation N.L. treated 188,647 tons for a recovery of 98,922 fine ounces. Gold recovery was at the rate of 10.49 dwts. per ton as compared with the previous year's recovery of 10.42 dwts. per ton when 182,589 tons yielded 95,114 ounces.

Reserves of ore at the 28th June were estimated to be 634,000 tons averaging 10.5 dwts. per ton.

Most of the production came from Crown reef workings off the Regent shaft. Stoping was concentrated between the Nos. 19 and 25 levels with a minor amount from the 29 level. Mining of remnants and cleaning down operations produced worthwhile tonnages from the 14 and 16 levels. Development commenced on the 34 level following completion of the 852 feet inclined internal shaft sunk below the 29 level. The No. 22 level Crown shear south drive was stopped at a distance of 10,000 feet south of the Regent shaft, where the reef terminated on a fault.

At the Princess Royal mine the No. 22 level north drive was advanced to a total of 4,767 feet from the Royal shaft. Development of this heading ceased following a rock burst near the face on the 16th September. Since then diamond drilling has been carried out from crosscuts to test the Royal shear below the level. Stoping was confined to the extraction of pillars and cleaning out operations between the 5 and 9 levels. This source of ore is expected to last for several years.

The North surface winze continued to operate throughout the year producing useful small tonnages from the 4, 5 and 6 levels. Diamond drilling from the surface was concentrated at sites north of Royal shaft and in the vicinity of the Norseman district hospital.

Little interest was shown in gold mining by prospectors during the year. The prospectors' compressor—rock drill outfit, purchased last year by the Department for use near Norseman, proved popular with tin prospectors.

MURCHISON GOLDFIELD.

161,847 tons of ore were treated in this goldfield for a return of 42,472 fine ounces of gold. This production was equal to 6.8 per cent of the State's total. In the previous year 55,477 ounces were obtained from the treatment of 168,226 tons.

Gold output from the various tenements in the *Cue and Day Dawn Districts* amounted to 53 ounces obtained from the treatment of 120 tons of tailings at Big Bell and from alluvial and dollied gold.

In the *Meekatharra District* 852 ounces were recovered from the treatment of 4,521 tons of ore. The more successful producers were Halcyon with 116 ounces from 2,290 tons and the

Prohibition with 95 ounces from 1,373 tons. State Battery sands treatment yielded 477 fine ounces of gold.

The *Mount Magnet District* produced 41,567 fine ounces of gold from the treatment of 157,326 tons of ore. The principal producer was *Hill 50 Gold Mines N.L.* with 41,201 ounces from 156,859 tons. Average recovery was 5.25 dwts. per ton which was over one pennyweight less than the previous year's average of 6.59 dwts. when 54,232 ounces were recovered from 164,671 tons.

The ore reserve at the 28th June was determined as 693,700 short tons at 4.7 dwts. per ton.

Development work completed during the year included shaft sinking 42 feet, driving 3,062 feet, crosscutting 1,248 feet, winzing 77 feet and rising 955 feet. Stope preparation development included in the above consisted of driving 2,501 feet, crosscutting 581 feet and rising 543 feet. Work was concentrated between the Nos. 12 and 13 levels. At the 2,760 feet horizon (No. 12 level) preparations were made for the construction of an internal shaft at co-ordinates 13332N/12051E. Access crosscuts, sinking winder site, main winder chamber, rope way rises and pilot shaft, have been completed. On the No. 13 level at 3,010 feet horizon an access crosscut and plat have been cut at the planned position of the shaft.

At the 657 feet level on the Morning Star lease a total of 454 feet of driving was completed off the underlay shaft. Pattern drilling disclosed an ore body of reasonable value. A vertical shaft is being constructed to exploit the ore body and at the end of the year sinking had reached 42 feet.

Eclipse Gold Mines N.L. reported the production of 147 fine ounces of gold from cleaning up around the Eclipse plant at Mount Magnet which ceased operations in October, 1963.

NORTH COOLGARDIE GOLDFIELD.

Production from this goldfield amount to 10,336 fine ounces of gold recovered from 27,781 tons of ore averaging 7.44 dwts., per ton. As a comparison, the production for the previous year was 13,880 fine ounces from 29,387 tons averaging 9.45 dwts. The output from this goldfield represented 1.6 per cent of the State's total.

In the *Menzies District, Moonlight Wiluna Gold Mines Ltd.* operating the Timoni mine at Mount Ida, produced 9,697 fine ounces of gold from the 24,910 tons of ore treated. Average recovery was 7.79 dwts per ton.

Development work for the year included driving 553 feet, crosscutting 53 feet, winzing and rising 280 feet. Ore breaking was concentrated on the 3, 4 and 5 levels while stopes on the lower levels were being emptied. At the end of the year, the ore reserves were limited to the broken ore remaining in the stopes. Operations at this mine ceased during March, 1967. During the 17 years that the company worked this mine, 231,631 fine ounces of gold were recovered from the treatment of 455,407 tons of ore.

Smaller producers in the district won 205 ounces from 1,627 tons.

In the *Ularring District* the production was 369 fine ounces of gold recovered from the treatment of 1,169 tons of ore. The principal producers were the *Oakley* with 156 ounces from 206 tons and the *First Hit* at Morley's Find with 111 ounces from 93 tons.

Eleven tons of ore from sundry claims in the *Niagara District* yielded 4 fine ounces.

In the *Yerilla District* the Yarri State Battery was opened for a short run when 64 tons from several producers yielded 61 fine ounces.

COOLGARDIE GOLDFIELD.

During 1966, 3,813 tons of ore were treated for a return of 5,636 fine ounces of gold. In the previous year 3,946 tons yielded 4,627 fine ounces.

The *Little Nipper* at Ryans Find produced 1,366 fine ounces of gold from 150 tons of ore. The ore was won from enrichments adjacent to flat south dipping across fractures on the narrow ore shear. The shaft has been sunk 186 feet to water level with current lateral development at the 150 feet horizon.

Formerly a prospecting area, the *Dorothy Gay* at Spargoville owned and operated by E.G. and K. Holman had a spectacular return of 2,866 fine ounces from 78 tons of ore of which 2,069 ounces were recovered from 0.2 tons of specimen stone. This stone was the richest seen in the district for several years and attracted a great deal of interest when it was being treated at the battery. The ore body on this mine is a steeply dipping quartz reef about one foot in width, occurring in greenstone country rock. The patch, was extracted at a depth of 20 feet adjacent to a fault-ore intersection. Further ore was obtained from shaft sinking to 40 feet.

In the Hampton Plains area P.P.L. 330 worked under tribute to Gold Mines of Kalgoorlie (Aust.) Ltd. yielded 177 fine ounces from the treatment of 651 tons of ore. The more successful of the smaller producers in the Coolgardie Goldfield were the *Hillside* with 187 ounces from 235 tons and the *Rayjax* with 85 ounces from 62 tons. Part time prospectors are very active in this goldfield.

BROAD ARROW GOLDFIELD.

Total production for the year was 2,275 fine ounces of gold recovered from the treatment of 8,634 tons of ore. Part time and week end prospectors were responsible for most of the production from this goldfield.

Work was suspended on the *Gimlet South* leases where in previous years low grade ore was obtained by open cutting methods. Following depletion of open cut reserves it was found necessary to revert to underground mining which proved uneconomic. Two hundred and seventeen ounces were obtained from the 4,077 tons crushed at the State Battery.

At Black Flag 174 tons from the *Bellevue South* mine yielded 356 fine onces. Good returns were also obtained from the *Prince of Wales*, at Grants Patch, with 188 ounces from 320 tons, the *Rona Lucille*, at Paddington, with 115 ounces from 248 tons and the *Renown*, at Ora Banda, with 110 ounces from 20 tons. Sands treated at the Ora Banda State Battery yielded 525 fine ounces of gold.

PHILLIPS RIVER GOLDFIELD.

The only producer in this field was *Ravensthorpe Copper Mines N.L.* with 1,389 fine ounces of gold recovered from 3,116 tons of auriferous copper concentrates exported to Japan. These concentrates also contained 624 tons of copper and 4,439 fine ounces of silver. Total tonnage treated at Ravensthorpe was 52,279 tons which included 8,573 tons of sand and residues from the Desmond dump, Two Boys, and Floater group.

The Elverdton shaft was extended one lift to the No. 6 level and a start made to develop this level. Stoping and development was concentrated on the 2 and 4 levels of the Desmond and on the 5 level of the Elverdton. Ore reserves as at the 30th June were reported as 110,600 tons.

EAST MURCHISON GOLDFIELD.

Eighty six per cent of the total production, of 1,044 fine ounces of gold recovered from 2,242 tons of ore, was obtained from mining operations at the Goanna Patch on Wildara Station in the Lawlers District.

At the *Mangilla* a 50 deep shaft was sunk on the north end of the mine to block out 600 tons of ore and to give through ventilation. Output for the year was 508 ounces from 597 tons. Production from the *Tahmoo* amounted to 150 ounces from 736 tons. *Central Norseman Gold Corporation N.L.* continued testing around the *Rowleys Find* leases and recovered 108 ounces from 363 tons. Other producers on Wildara Station produced 127 ounces from 308 tons.

The only producer of note in the *Black Range District* was the *Scheelite* with a return of 136 fine ounces from the treatment of 218 tons at the Sandstone State Battery.

YILGARN GOLDFIELD.

Gold production in the Yilgarn Goldfield has reached what is probably an all time low. 1,815 tons of ore were treated for a recovery of 1,020 fine ounces of gold. During the year the standard gauge railway line was completed to Koolyanobbing and iron ore production will take over as the major source of the Districts mineral wealth.

The *Frances Furness* at Marvel Loch produced 265 fine ounces of gold from the treatment of 715 tons of ore. The working party was disbanded and the owner's hopes rest with the return of Hill 50 Gold Mines N.L. to the district or the activities of La Porte Titanium (Aust.) Ltd which has a geological party established close to Nevoria.

A consistent small producer, the *Constance Una* at Parker's Range produced 241 fine ounces from 175 tons.

There were no other producers of note except for the State Battery which treated sands for a return of 296 fine ounces of gold and 250 fine ounces of silver. Since gold production ceased, last year, the plant at the *Radio* mine in the Golden Valley centre has been used to crush metal for road and railway projects in the district.

PILBARA GOLDFIELD.

Gold production in this goldfield increased to 917 fine ounces from 1,163 tons as compared with the previous years output of 508 fine ounces from 920 tons. The Bamboo Creek centre was responsible for four fifths of the total production. The *Prophecy* with 667 fine ounces from 570 tons was the principal producer followed by the *Kitchener* with 72 ounces from 51 tons. Treatment of battery sands yielded 87 ounces.

MOUNT MARGARET GOLDFIELD.

Production of 715 fine ounces of gold from 773 tons of ore was an improvement on the previous year's output of 257 fine ounces from 1,213 tons. Cleaning up around the *Sons of Gwalia* mine returned 302 fine ounces and State Battery sands yielded 126 fine ounces. No production was recorded for the *Mount Margaret District* and only 26 ounces from the *Mount Morgans District*.

NORTH EAST COOLGARDIE GOLDFIELD

During 1966, 487 fine ounces of gold were recovered from the treatment of 498 tons of ore. The only producer of note was the *Kanowna Red Hill* with 306 ounces from 90 tons of ore and specimen stone. Another party is unwatering the *White Feather* mine which should be producing in the coming year. Exploration groups are interested in the nickel, cobalt and manganese prospects in this goldfield.

GASCOYNE GOLDFIELD.

The *Star of Mangaroon*, with 350 fine ounces of gold recovered from 143 tons crushed at the Meekatharra State Battery, was the only producer in this goldfield.

Other sources within the State produced 84 fine ounces of gold.

MINERALS OTHER THAN GOLD.

The production of minerals, other than gold, for 1965 and 1966 is shown in the table "H".

TABLE H

Mineral Output except Gold

Mineral	1965		1966	
	Tons	Value	Tons	Value
		$A		$A
Asbestos—				
Chrysotile	402.00	57,678	119.01	19,326
Crocidolite	9,279.94	1,746,080	11,464.57	2,414,905
Barite	750.75	6,006	1,809.65	26,660
Bauxite	486,718.00	8,908,080	805,192.00	14,589,120
Bentonite	921.45	3,638	563.50	2,582
Beryl	13.08	2,890	12.63	2,992
Bismuth (lb.)	....	....	95.70	88
Building Stone	1,286.00	15,978	1,674.00	10,060
Clays	224,117.50	346,714	206,664.35	356,186
Coal	993,740.80	4,409,972	1,061,094.65	4,562,087
Copper—				
Ore and Concentrates	2,051.50	254,920	3,268.29	518,134
Fertiliser Grade	1,078.76	99,234	962.27	87,954
Diatomaceous Earth	....	....	45.50	1,955
Dolomite	....	....	5.00	75
Felspar	1,384.00	19,488	1,282.00	18,050
Fullers Earth	63.00	534	....	....
Glass Sand	9,259.00	12,168	28,219.00	16,482
Gypsum	46,607.00	89,154	41,884.00	79,873
Ilmenite	392,891.22	3,852,376	470,896.12	4,621,179
Iron Ore (for pig)	65,623.00	1,870,958	93,740.00	2,865,043
Iron Ore (exported)	2,240,939.00	4,444,538	4,166,329.92	18,268,833
Lead Ore and Concentrates	4,877.93	392,638	2,681.30	104,408
Leucoxene	484.00	21,612	755.89	31,273
Limestone	565,830.00	627,372	577,435.70	650,666
Lithium Ore—Petalite	310.00	4,742	933.00	14,124
Magnesite	199.08	3,176	135.07	1,959
Manganese	100,208.20	2,151,852	136,747.94	3,047,909
Monazite	1,068.00	104,302	1,894.62	221,277
Ochre	186.65	2,240	207.00	4,140
Phosphatic Guano	15.00	300	....	....
Pyrite	59,179.94	768,244	76,136.22	1,023,071
Rutile	225.00	15,988	576.38	40,515
Scheelite	....	....	0.52	771
Semi-Precious Stones	....	....	0.29	504
Silver (fine oz.)	290,622.68	340,412	223,182.96	261,271
Talc	7,087.79	205,410	9,155.34	231,625
Tantalo-Columbite	9.87	17,746	4.71	19,691
Tin Concentrate	675.58	1,556,514	589.01	1,231,570
Zircon	27,879.67	750,268	26,497.53	851,411
Totals	....	33,103,222	....	56,197,769

Brief notes on mineral production are given below.

ASBESTOS.

Chrysotile—Ten men were employed during the four months' operations of the Soansville mine. Output of fibre from the Comet mill at Marble Bar was 119 tons valued at $19,326. Mining operations ceased as the owner had difficulty in getting experienced miners and because of the inability of the mill to separate the fibre into its various grades.

Crocidolite—Australian Blue Asbestos Ltd. at Wittenoom produced, from 235,289 tons of ore, 11,465 tons of fibre valued at $2,414,905. The average number of men employed throughout the year was 326. Ore breaking ceased on the 7th December and the mine closed down at the end of the year. The decision to close the mine was made following progressive annual losses and because further work would be uneconomic. The mine was sold to Messrs. Hancock and Wright.

Prior to the mine closure the manager had been experimenting with a high back long wall method of stoping. This method was developed following the use of hydraulic props as temporary supports in the controlled caving of the low back long wall stopes. Preliminary results obtained with the high back method were encouraging and prior to the closure of the mine it had been decided to mine the Eastern creek ore body by this method.

BARITE.

Producers at Chesterfield, near Meekatharra, and Cranbrook in the South West obtained 1,810 tons of barite valued at $26,660 f.o.r.

BAUXITE.

Alumina production increased by 94,684 tons to 243,152 tons during 1966 as compared with the output for the previous year. The nominal value of this output was $14,589,120.

Western Aluminium N.L. (wholly owned subsidiary of Alcoa of Australia Pty. Ltd.) railed to the Kwinana refinery 805,192 tons of bauxite obtained from zones E, B and C in the rifle range area near Jarrahdale. Mining has increased to keep pace with the continued expansion of the Kwinana alumina refinery.

Construction of two additional railway bins was commenced in September. The 1967 output of 4,000 tons of ore per day will be obtained from shallow pits using the following equipment. 2 x wagon drills (Air Track), 2 x RB.38 shovels, 4 x Euclid R.24 trucks, 1 x Gradall trench digger, 1 x Euclid L20 front end loader, and a Le Tourneau LW16 angle dozer.

Expansion at Kwinana included the construction of a second unit to boost alumina production to about 400,000 tons per annum. A start has been made on the construction of the third unit of the refinery.

BENTONITE.

Three operators working lake deposits during the summer months obtained 563 tons valued at $2,582. This production came from the Cunyidi-Marchagee area which is about 150 miles north of Perth.

BERYL.

Very little interest was shown in the production of beryl. No production was reported from Coolgardie, Pilbara and West Pilbara Goldfields. Two producers, both in the Yalgoo Goldfield, obtained a total of 12.63 tons containing 147.08 units of beryllium oxide valued at $2,992.

BISMUTH.

Ninety-six lb valued at $88 was obtained from the Brockman Creek area in the Pilbara Goldfield.

BUILDING STONE.

Production from mining tenements, granted under the provisions of the Mining Act, was 1,674 tons valued at $10,060. Production included 1,280 tons of quartzite popularly known as Toodyay Stone, 77 tons of granite facing stone from Watheroo, 248 tons of sandstone from Mount Barker and 69 tons of spongolite from Ravensthorpe and the Fitzgerald river.

CLAYS.

Reported clay production for the metropolitan area, Clackcline, Glen Forrest, Mount Kokeby, Kalgoorlie and Goomalling totalled 206,664 tons valued at $356,186. Output is still in excess of the above tonnage as all production is not reported to this Department. Most of the clay came from pits in the area between Byford and Herne Hill.

COAL.

The total output from all mines in the Collie Coalfield was 1,061,095 tons valued at $4,562,087. This production was the highest ever recorded on the field and was 67,354 tons higher than for 1965. Each of the two deep mines and the open cut exceeded their previous individual record levels.

Production from the Muja open cut, operated by the *Griffin Coal Mining Co. Ltd.*, was 567,839 tons which represented 53.5 per cent of the total output for the coalfield. Except for 55,577 tons from the Centaur area, all the coal was obtained from the Hebe and Galatea seams in the East Extension Area. Overburden removed to uncover coal was 2,343,491 cubic yards in the solid. On the basis of 1 cubic yard of coal "in situ" weighing 1 ton then the ratio of overburden removed to coal produced was 4.13 to 1.

A new road was constructed to the Centaur coal handling plant and construction of a new road to the Muja generating station was nearly completed by the end of the year. Lighting of a good standard is provided at the railway siding, screening plant and in and around the cut workings. The East Extension area is particularly well illuminated by 400W mercury vapour lamps suspended from cables spanning the excavation. Additional earth moving equipment purchased during the year included 1 x RB71. 3½ cubic yard excavator, 2 x International Payloaders each of 50 tons capacity, 2 x Fodens of 17 tons capacity, and 1 x Caterpillar D9 bulldozer.

Western Collieries Ltd. produced 493,256 tons of coal from its two deep mines Western No. 2 and Western No. 4. A record output of 389,499 tons from Western No. 2 exceeded the previous year's output by 22,065 tons. This mine is the largest single deep mine producer that has been worked on the field and it has a good production potential for the future. As part of a new programme of development for the west side of the mine, drivage of six new development headings (Cullen Headings) was commenced at right angles to, and from the end of the No. 3 West headings and a drift was driven from No. 4 Cullen to the surface. By the end of the year, work was well advanced toward equipping the new drift and the No. 4 heading with a conveyor system which will feed into a 200 ton capacity bin near the portal. This area will be developed as rapidly as possible depending on labour available from Western No. 4.

Western No. 4 with a record output of 103,807 tons is expected to close down, except for salvage operations, during the latter half of 1967. Work was concentrated on solid drivage and pillar splitting mainly to the east of the previous main slants. The stripping of an additional two yards of coal from the sides of selected pillars and drivage into the centre of pillars was carried out safely on a retreating basis. There was no evidence of movement caused by extra weight on the smaller pillars. Production of coal from the East Portal ceased in December.

There was a significant improvement in the standard of amenities on the surface. A new change house was completed at the Muja open cut and at the Western No. 2 mine work was well advanced on similar construction. The Griffin company has also provided refrigerators at mess rooms and in the mobile crib cabin.

COPPER

Ravensthorpe Copper Mines N.L. produced 3,116 tons of concentrate from 43,706 tons of ore from the Elverdton leases and the Marion Martin mine, and 8,573 tons of residues from the Desmond dump, Two Boys, and the Floater group. The concentrate contained 624 tons of copper, 1,389 fine ounces of gold and 4,439 fine ounces of silver. The Elverdton shaft was extended one lift to the No. 6 level and a start made to develop this level. Stoping and development was concentrated on the 2 and 4 levels of the Desmond and on the 5 level of the Elverdton. Ore reserves as at the 30th June were reported as 110,000 tons. Level development work completed during 1966 included driving 718 feet, crosscutting 337 feet, rising and winzing 242 feet.

Western Mining Corporation Ltd. and T. Simms developing prospects in the Warburton Range produced 152 tons of ore which yielded 54 tons of copper. In addition 201 tons of 10.75 per cent fertiliser grade ore was produced.

Production of copper ore, for use as a trace element in fertilisers, was 962 tons as compared with 1,079 tons for the previous year. Grade was also slightly lower at 14.11 per cent Cu as compared with the 1965 average grade of 14.92 per cent Cu.

The Thaduna Copper Mining Co. Pty. Ltd. was the leading producer of fertiliser grade ore with 488 tons of concentrate averaging 12½ per cent Cu valued at $42,788. Ore breaking in the open cut ceased early in the year and except for treating broken ore and cleaning up around the plant the only work being undertaken was a diamond drilling programme. The future of the mine depends on the success of this exploration.

Other notable producers of copper ore were *M. Alac* at Ilgarari with 122 tons of 25.16 per cent ore valued at $20,505, *K. J. McPherson* at Nullagine with 63 tons of 21.06 per cent ore valued at $8,460 and *R. Lee* at Thaduna with 26 tons of 21.99 per cent ore valued at $4,476.

DIATOMACEOUS EARTH

Universal Milling Co. Pty. Ltd. obtained 45½ tons from a deposit near Yanchep.

DOLOMITE

Five tons of dolomite was obtained by *Westralian Ores Pty. Ltd.* from a stockpile at the Mount Magnet deposit.

FELSPAR

Australian Glass Manufacturers Co. Pty. Ltd. reported the production of 1,282 tons from their quarry at Londonderry in the Coolgardie Goldfield. In addition 933 tons of petalite valued at $14,124 was obtained from the same source.

GLASS SAND

Production from the Lake Gnangara deposit amounted to 12,369 tons valued at $16,482. Ready Mix Concrete (W.A.) Pty. Ltd. exported to Honolulu 15,850 tons of sand (value not available for publication) obtained from Jandakot situated about seven miles south east of Fremantle.

GYPSUM

Plaster manufacturers obtained their supplies of gypsum from Yellowdine, Lake Brown, Lake Cowcowing and Lake Cowan. Plaster of Paris reported as manufactured was 21,739 tons from 30,299 tons of gypsum. The source of the 1,728 tons of gypsum used in cement manufacture was Nukarni, north of Merridin. Total production for the year was 41,884 tons valued at $79,873 f.o.r.

ILMENITE, LEUCOXENE, MONAZITE, RUTILE, ZIRCON

Sales of ilmenite totalled 470,896 tons valued at $4,621,179. Minerals associated with ilmenite returned $1,144,477 to the producers.

Western Titanium N.L. at Capel produced 174,258 tons of ilmenite assaying 54.63 per cent titanium dioxide, 550 tons of leucoxene, 1,138 tons of monazite, 576 tons of rutile and 10,297 tons of zircon. Mining by sluicing was continued in No. 4 pit until July when operations were transferred to No. 5 pit and a new concentrator commissioned. During the year 664,800 tons of ore was obtained from an area totalling 13 acres. The company has an estimated ore reserve of 9½ million tons of heavy mineral.

Western Mineral Sands Pty. Ltd. at Capel produced 130,131 tons of ilmenite assaying 53.74 per cent TiO_2. Mining is straightforward using front end loaders for digging the sand delivering to a cleaning screen and bin in the centre of the pit. The cleaned sand is pumped to the wet plant which consists of a 3 stage double Reichert cone concentrator. The mixed concentrate is pumped to drying bays and thence to the dry treatment plant where the ilmenite is recovered.

Westralian Oil Ltd. produced 85,685 tons of ilmenite assaying 58.75 per cent TiO_2, 206 tons of leucoxene, 613 tons of monazite and 13,887 tons of zircon from the Yoganup deposit. Early in 1966 this company took over the mining operations from the contractors Westralian Mining and Oilfield Services. There was no change in mining or concentrating practice. Ore is won in the pit by dragline or power shovel and carted to the wet concentrating plant which consists basically of banks of Humphrey spirals. The concentrate is then carted about 8 miles to the dry treatment plant at Capel.

Ilmenite Minerals Pty. Ltd. operating at Wonnerup near Busselton produced 47,275 tons of ilmenite, 47 tons of monazite and 1,584 tons of zircon. Work was concentrated on Sussex Location 7 near the Sabina river where a drag line excavator was used to dig the sand. Wet concentration of the heavy minerals was achieved using a bank of revolving cones. This company (previously Ilmenite Pty. Ltd.) and Cable (1956) Ltd. are now wholly owned subsidiaries of Kathleen Investments (Aust.) Ltd.

Cable (1956) Ltd. at Bunbury produced 33,548 tons of ilmenite, 97 tons of monazite, and 729 tons of zircon obtained from deposits at Bunbury and Stratham. The company has a suction dredge and Reichert cone concentrators operating at Stratham. The mixed concentrate is then carted about 12 miles to the dry separation plant at Bunbury.

IRON ORE.

During 1966, *Dampier Mining Co. Ltd.* (previously Australian Iron and Steel Ltd.) shipped to the Eastern States 2,615,161 tons of iron ore averaging 63.75 per cent Fe. The nominal value of this output was $5,180,599. In addition the company exported 141,346 tons of 65.79 per cent ore valued at $1,045,711 f.o.b. Production shipped from Koolan Island was 1,505,124 tons and from Cockatoo Island 1,251,383 tons. The labour force on the two islands totalled 316 persons.

Production from the Dowd's Hill deposit at Koolyanobbing will commence early in the new year. The standard gauge railway from Kwinana has been completed to Koolyanobbing, and Dampier has installed an 84 in x 60 in jaw crusher, 2 x Jaques 5½ ft. traylor gyratory secondary crushers, conveyors and constructed 6 x 2,000 ton capacity bins at the railway siding. Quarry equipment available at the site of operations include 2 x 6 cubic yard P & H electric shovels and 6 x 50 short tons capacity Haulpack trucks.

The *Charcoal Iron and Steel Industry* at Wundowie obtained 93,740 tons of 62 per cent ore from the Koolyanobbing deposit. Pig iron produced was 56,075 tons valued at $2,865,043.

Goldsworthy Mining Ltd. reported the sale overseas of 853,782 tons of iron ore assaying 65.15 per cent Fe and valued at $8,246,170. Construction of an ore terminal, ship loading pier, dredging, 71 miles of standard gauge railroad, and the development of an open pit mine at Mount Goldsworthy took fifteen months to complete. It is anticipated that future shipments of ore will be at the rate of 2.5 million tons per annum to markets in Japan and possibly Europe.

At the Mount Goldsworthy mine, the following specifications have been adopted for pit design.

Bench height—40 feet. Final bench width—40 feet.

Haul road maximum grade—8 per cent.

Berm widths—40 feet every third level—17 feet for other levels.

Final pit slope 40 degrees.

The final waste to ore ratio will be about 1.25 : 1.00 for the recovery of approximately 42 million tons of open pit ore.

Hamersley Iron Pty Ltd. exported 203,917 tons of 65.24 per cent ore valued at $1,855,911 f.o.b. Dampier. Construction and commissioning of all production sections of the direct shipping ore project were completed by August, 1966. This included mining, crushing and screening facilities at Mount Tom Price; the stockpiling and shipping facilities at Dampier, and the 182 miles of standard gauge railway linking mine and port. Almost 5 million tons of ore and waste had been mined by the end of the year. About half this amount was stockpiled as seconds and 209,000 tons was dumped as waste. Over a million tons of crushed ore was railed to the portsite. Work started during July on the construction of a 2 million tons per annum pellet plant at Dampier. This plant will be the largest of its type in the world and it is scheduled for completion early in 1968.

At Koolanooka Hills (near Morawa) *Western Mining Corporation Ltd.* mined and exported 352,123 tons of 59.64 per cent iron ore valued at $2,730,282 f.o.b. Geraldton. Thirty feet high benches have been established and ore won from seven of these situated between 1,155 and 1,335 feet above sea level. Drilling units in use were two truck mounted wagon drills and a Crawlmaster down the hole hammer unit drilling 6 inch diameter holes on a 15 feet x 15 feet pattern. Holes are slightly inclined and drilled 2-3 feet below grade. Ammonium nitrate-fuel oil, fired by detonating cord initiated by detonator and safety fuse, was the principal explosive used. Broken ore is loaded into Haulpack trucks by a 4½ cubic yard P & H shovel. About 100,000 cubic yards of material is handled per month; at present a large percentage of this is overburden. Sixteen trains per fortnight, loaded with 1,550 tons of crushed and screened ore, are needed to keep the stockpile at Geraldton supplied with shipping ore. At the port the ore is stockpiled by conveyor and stacker, and a bucket wheel reclaimer and conveyors are used for ship loading.

LEAD.

Lead concentrate sales from the Northampton field amounted to 644 tons valued at $88,452. The *Mary Springs* lead mine was the leading producer with 197 tons of concentrate containing 158 tons of lead valued at $32,684. Some of the high grade ore was drummed directly at the mine. The ore was obtained from stoping above the 100 feet level, the bottom level of the mine. A company has the mine under option and completed 4,191 feet of diamond drilling to prove the ore body at a depth of approximately 300 feet. Apparently results were promising and it is possible that in 1967 shaft sinking from the surface will be started.

The *Nooka* lead mine operated for most of the year but operations were suspended in November following a falling off of grade of ore mined. Production was 238 tons of concentrate containing 166 tons of lead valued at $30,025. Mining operations were confined to stoping above the 276 feet level.

2,037 tons of lead-zinc ore from the *Devonian* mine in the West Kimberley Goldfield yielded 245 tons of lead, 644 tons of zinc, and 4,120 fine ounces of silver with a total value of $20,688. At present this mine is inoperative through lack of ore.

LIMESTONE.

Reported production of limestone was 577,436 tons valued at $650,666. Total annual production would exceed the figures quoted above as all production within the State is not reported.

Limestone for cement manufacture was obtained from the South Coogee area where the stone is ripped and pushed into dumps for loading. Quarries at Beaconsfield and Wanneroo supplied the needs of the building industry for foundation stone. Limestone used as a flux by the Charcoal Iron and Steel Industry was mined, crushed and screened at Beaconsfield. Only two small companies operated lime kilns at quarry sites. These will probably cease production in 1967.

Limestone rubble, for road construction, is very popular and most quarry operators have little trouble disposing of this product.

LITHIUM ORES.

Australian Glass Manufactureres Co. Pty. Ltd. obtained 933 tons of petalite from the felspar quarry at Londonderry in the Coolgardie Goldfield.

MAGNESITE.

The sale of 135 tons of magnesite stockpiled at Esperance yielded $1,959 f.o.b. Norseman Gold Mines N.L. has taken an option over the deposit near Ravensthorpe and a 600 ton trial parcel of crude magnesite was exported to Japan. Reserves are said to be at least 5 million tons.

MANGANESE.

Exports from Port Hedland totalled 95,743 tons of 51½ per cent Mn ore valued at $2,270,840 f.o.b. The principal producer, *Mt. Sydney Manganese Pty. Ltd.* sold 53,510 tons obtained from mineral claims at Woody Woody. Reported production from open cut mining at Woody Woody was 71,500 tons of which 69,000 tons were carted to the Port Hedland stockpile.

From M.C. 487 near Woody Woody, *Westralian Ores Pty. Ltd.* reported breaking and carting 51,152 tons to Port Hedland and exporting 42,233 tons valued at $1,000,505. This company also mined manganese at Horseshoe and shipped from Geraldton 19,682 tons of 38 per cent Mn ore valued at $318,684. A 100 ton parcel of unknown grade valued at $1,599 was also exported by Westralian Ores.

The *Broken Hill Pty. Ltd.* obtained 21,223 tons of 46½ per cent Mn ore, valued at $456,787, from a deposit in the Mount Fraser area in the Peak Hill Goldfield. All mining operations for manganese in the Peak Hill Goldfield was carried out by Westralian Ores Pty. Ltd., which company worked in the Mount Fraser area for the first half of the year and then transferred to Horseshoe.

NICKEL.

The discovery of high grade nickel sulphide, at Kambalda about 30 miles south of Kalgoorlie, in a diamond drill hole put down by *Western Mining Corporation Ltd.* in February made world news and precipitated an intensive search for minerals in the eastern goldfields. The possibility of economic nickel deposits in the area was first appreciated by prospectors J. Morgan and G. Cowcill who reported the occurrence of low grade nickel in iron oxides near the present shaft site.

Drilling to the end of the year had established ore reserves in the order of 1,300,000 tons of 5.1 per cent nickel plus 600,000 tons at 2.1 per cent in lower grade zones. The high grade east dipping sulphide ore occurs at or near a contact between serpentinite overlaying basalt. The structure is complicated by local undulations and porphyry intrusions.

A three compartment shaft was commenced in July and had attained a depth of 425 feet by the end of the year. Sinking was here temporarily suspended to allow for level development. A treatment plant capable of treating 500 tons per day is being erected. Initial treatment will include grinding followed by magnetic separation to remove pyrrhotite and flotation to separately recover nickel and copper sulphides. Concentrates will be shipped through Esperance. It is anticipated that production will commence mid 1967. Much work has been done to provide housing, roads, water supply and power to the project. Water will be made available by the Country Water Supply and requires 11 miles of pipe line to be laid from Spargoville. Power is being supplied from the Gold Mines of Kalgoorlie (Aust.) Ltd. station at Trafalgar and a local power station of 4.4 megawatt capacity is planned.

OCHRE.

The *Universal Milling Co. Pty. Ltd.* obtained 207 tons of red oxide from the Weld Range deposit in the Murchison.

PYRITE.

Norseman Gold Mines N.L. treated 129,417 tons of ore in the heavy media separation plant followed by flotation to give 54,026 tons of pyritic concentrate containing 25,612 tons of sulphur. The concentrate was railed to superphosphate works in the metropolitan area. Value of production was $833,432 f.o.r. Norseman. Ore reserves as at the 31st October were 1,368,000 tons. Mining was confined to the Nos. 6 and 7 levels with increased production at the 7 level as sources of ore above the 6 level were depleted.

Gold Mines of Kalgoorlie (Aust.) Ltd. forwarded to works at Fremantle 22,110 tons of auriferous pyritic concentrate containing 7,586 tons of sulphur valued at $189,639.

SCHEELITE.

Half a ton of scheelite worth $771 was won from prospecting area 7,765 situated at Burbanks several miles south of Coolgardie.

SEMI PRECIOUS STONES.

Various rock collecting enthusiasts reported the production of about a quarter of a ton of beryl, topaz and chalcedony from deposits in the Murchison and Broad Arrow Goldfields.

SILVER.

Silver as a by-product of gold, copper and lead mining amounted to 223,183 fine ounces valued at $261,271.

TALC.

Three Springs Talc Pty. Ltd. produced 9,155 tons, valued at $231,625, from their open cut at Three Springs. This production represented an increase of 2,000 tons on the previous year's output.

TANTALO-COLUMBITE.

4.71 tons of concentrate, containing 254.39 units of Ta_2O_5 valued at $19,691 were produced during 1966. The producing centres were Wodgina and Tabba Tabba in the Pilbara with 59.22 units, Londonderry in the Coolgardie goldfield with 22.27 units, Warda Warra in the Yalgoo goldfield with 106.64 units, and Greenbushes with 66.26 units. The output from Greenbushes was obtained during tin mining operations.

TIN.

Production for the year was 589 tons of concentrate containing 406.45 tons of the metal valued at $1,231, 570. Tin producers in the Pilbara were responsible for the production of 564 tons of concentrate. The principal producer was *Cooglegong Tin Pty Ltd.* with 215 tons of concentrate recovered at the rate of 2.5 lbs. per cubic yard treated. The tin was obtained from various mining tenements in the Spear Hill area. Other notable producers in the Pilbara were *J. A. Johnston and Sons Pty. Ltd.* at Eleys and Coondina with 144 tons, *Pilbara Tin Pty. Ltd.* at Moolyella with 42 tons, *H. V. Leonard* at Moolyella with 39 tons, *M. R. Edwards* at Moolyella with 38 tons, and the *D. D. Mining Co.* also at Moolyella with 31 tons of concentrate. Increasing interest has been shown in the production of tin from known and new fields namely Moolyella, Cooglegong, Hartigans, Eleys, Pinga Well and Pilgangoora.

Good general rains have provided adequate water supplies on all except the Moolyella field.

Output from the Greenbushes field was 21½ tons of concentrate valued at $46,856. *Greenbushes Tin N.L.* with a reported output of 14 tons of concentrate lost two month's production when the dredge foundered on the 10th January. Dredging was resumed in March after extensive modifications were made and additional pontoons added to the dredge.

The Norseman State Battery crushed 614 tons of tin ore obtained by prospectors working in the Mount Woolyeenyer area. The ore yielded 3.66 tons of concentrate containing 2.32 tons of tin valued at $7,091. Norseman Gold Mines N.L. is interested in the area and has completed 17 diamond drill holes totalling 2,342 feet. Core obtained from one hole assayed 0.75 per cent tin over a width of 10 feet 4 inches.

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

14th July, 1967.

APPENDIX NO. 1

State Mining Engineer:

REPORT ON DRILLING ACTIVITIES FOR YEAR ENDED 31st DECEMBER, 1966

For the fourth year in succession I report an increase in the footage drilled by the branch. A total of 19,849 feet having been completed during the period under review, an increase of 5,519 feet on the figures reported last year.

Of 14 rigs on the drilling section strength, three were not engaged on departmental business during the period. However, these three were on hire to operators drilling at various centres, throughout the State. Our operations were widespread ranging from Wyndham in the north to Esperance in the south.

New plant coming in to the section during the year comprised two Ruston Bucyrus 22 R.W. well drills, two new Leyland eight ton trucks and four—two berth aluminium caravans. An additional pump for handling drilling mud was also purchased. This is of a novel type called an induced flow having a capacity of 9000 g.p.h. and being self priming to 25 feet.

Activities during the year have been hampered seriously by an acute shortage of suitable labour.

Rig No. 2 (Failing M1) completed 3,932 feet for the year. The plant was operated by J. Grill under contract arrangements with the department. Hole No. 4 at Gin Gin was advanced from 1,556 to 1,758 feet and completed. Other holes were done at this centre and one completed at a depth of 1,812 feet near Three Springs.

Rig No 3 (A.3000) was on hire to Canadian Southern Cross Mines and Nil footage is recorded for this machine.

Rig No. 4 (A.2000) was engaged on dam site investigations for the Metropolitan Water Board at South Dandalup and 68 feet were drilled when the programme was completed.

Rig No. 5 (A.2000) drilled 1,000 feet in one hole near Doodlakine for the Australian National University in a scientific research programme investigating the granite mantle. This plant was also hired to Canadian Southern Cross Mines during the year.

Rig No. 6 (A.2000) was on hire to Pickands Mather for a full year engaged on operations based at Halls Creek.

Rig No. 7 (F20). This plant completed 928½ feet for the year. A shallow hole of 43 feet to provide an earth for the electrical system at the Bickley Observatory was first drilled. On the Moochalabra Creek some miles from Wyndham 729½ feet were drilled investigating dam site conditions for the P.W.D. At Fremantle 156 feet were completed on wharf extension work.

Rig No. 8 (E500) was hired to four different firms during the year but the footage completed by this machine has not been returned and Nil footage is recorded against the plant.

Rig No. 9 (Gemco Auger) completed 2.585 feet for the year in 37 holes at Arrino and Fremantle.

Rig No. 10 (Failing 750) was engaged at Cockburn Sound and Fremantle on proposed harbour works where 2,468 feet were done in 40 holes. At Pinjarra a percussion bore was deepened from 850 feet to 941 feet in an attempt to obtain an uncontaminated core sample for palaeontological examination. A total of 2,559 feet was drilled by this machine.

Rig No. 11 (Mayhew 2000) completed 4,535 feet for the year in two holes, one of 2,605 feet at Gin-Gin and one of 1,930 feet at Busselton.

PERCUSSION RIGS

Rig No.1 (Ruston Bucyrus No. 22 R.W.) drilled 760 feet in two holes near Pinjarra on a Water Resources Survey.

Rig No. 2 (R.B. 22R.W.) completed 1,098½ feet for the year. 131 feet at Gnangara and 967½ feet at the Yule River near Port Hedland investigating ground water resources.

Rig No. 3 (R.B. 22R.W.) was received by the Department in July and went to the Yule River where 940½ feet were completed.

Rig No. 4 (R.B. 22R.W.) entered service in August and went to Esperance where 1,442½ feet were drilled.

GENERAL

Considerable quantities of drilling equipment have been loaned or hired to drillers during the year, which involves the employees at the depot in much added work. The income received from the plant hire must be a considerable offset against the costs involved.

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

J. HADDOW,
Inspector of Mines (Drilling).

26th April, 1967.

TABLE SHOWING FOOTAGE DRILLED FOR YEAR ENDED 31st DECEMBER. 1966

Rig No.	Machine	Place	Purpose	Footage	Total	Basis	Remarks
2	Failing M1	Gingin 4	Water Supply	202	....	Contract	
		Gingin 5A	Water Supply	214	....	....	
		Gingin 5	Water Supply	1,704	....		
		Three Springs 1	Water Supply	1,812	....	....	4 holes.
					3,932		
3	A. 3000	Northampton	....	....	Nil	....	Hired to C.S.X.
4	A. 2000	South Dandalup	Dam Foundations	68⅓	68⅓	Wages	Hired to Ass. D. Drillers.
5	A. 2000	Doodlakine	University Research	1,000	1,000	Wages	Hired to Canadian S.X.
6	A. 2000	....	....	....	Nil	....	Hired to Pickands Mather.
7	F. 20	Bickley	Earth for Electrical System	43	....	Wages	
		Wyndham	Dam Foundation	729½	....	....	6 holes.
		Fremantle	Wharf Extension	156	....	....	
					928½		
8	E. 500	....	....	....	....	....	Hired to Geo-Drillers, Clough & Son, Tech. Drillers, Canadian S.X.
9	Gemco.	Arrino	Geological Information	2,310	....	Wages	28 holes.
		Fremantle Harbour	Wharf Extension	275	....	Wages	9 holes.
					2,585		
10	Failing 750....	Cockburn Sound	Harbour Works	2,178	....	Wages	33 holes.
		Fremantle Harbour	Harbour Works	290	....	....	7 holes.
		Pinjarra	Water Resources	91			
					2,559		
11	Mayhew 2000	Gingin Brook	Geological Information	2,605	....	Wages	
		Busselton	Geological Information	1,930	....	Wages	
					4,535		
			PERCUSSION RIGS				
1	R.B.22R.W.	Pinjarra 10	Water Resources	570	....	....	
		Pinjarra 14	....	190	....	....	2 holes.
					760		
2	R.B.22R.W.	Yule River	Water Resources	967½	....	....	7 holes.
		Gnangara	....	131	....	....	
					1,098½	....	
3	R.B.22R.W.	Yule River	Water Resources	940½	940½	....	8 holes.
4	R.B.22R.W.	Esperance	Water Resources	1,442½	1,442½	....	21 holes.
			Grand Total		19,849		

APPENDIX No. 2.

20th March, 1967.

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 1966.

Mining Law Examination.

An examination in Mining Law for the Mine Managers' Certificate of Competency was held on 18th April, 1966.

Details were as follows:—

Entries	10
Admitted	10
Pass	6
Failed	3
Did not sit	1

The names of the successful candidates were:—

First Class

R. F. Ward.
F. N. Lubbock.
B. J. Hurley.
R. J. George-Kennedy.
V. R. Gamble.
G. J. Dodge.

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

Underground Supervisors Examination.

The written examination was held on 6th September, 1966 and applications were received from the following centres:—

Kalgoorlie	12
Norseman	7
Ravensthorpe	2
Wittenoom	1
	22

Of the twenty-two (22) applications, twenty-one (21) were accepted, five of these being accepted with the proviso that evidence of First Aid be submitted by 26th August, 1966 and one with the proviso that evidence of practical experience be submitted by 9th August, 1966. All of the twenty-one (21) approved applicants sat for the examination.

The results were as follows:—

Examined	21
Passed	19
Failed	1
Deferred (To sit for Oral Examination in 1967.)	1

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

Andrews, David Noel Max—Kalgoorlie.
Bell, Donald Robert—Kalgoorlie.
Bell, James—Kalgoorlie.
Byfield, Hubert Henry—Kalgoorlie.
Condren, Bernard—Kalgoorlie.
Cruickshank, Alfred Colin—Kalgoorlie.
Denison, Joseph Lionel—Norseman.
Gatti, Victor Francis—Norseman.
Hill, Joseph William—Kalgoorlie.
Lahti, Reijo Kalevi—Norseman (Restricted to Mines on the underlay system).
Lonsdale, Maurice Royal—Kalgoorlie.
Malacari, Arthur James—Kalgoorlie.
Malseed, Ross James—Kalgoorlie.
New, Edward Jack Guy—Norseman.
Siviour, Matthew Alexander—Kalgoorlie.
Sloan, Keith—Norseman.
Taylor, Ben Llewellyn—Norseman.
Venturini, Giandomenico—Kalgoorlie.

Mr. T. D. Renton of Ravensthorpe was granted a pass in the examination, conditionally on his passing the First Aid Certificate.

Mine Managers Certificates

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

First Class

A. A. Wells.
W. B. Edlington.
V. R. Gamble.
R. F. Ward.
F. N. Lubbock.

Second Class

F. Hodge.
G. Abatematteo.

One application for a First Class Certificate was refused on the grounds that the applicant had failed to comply with the regulations, as advised on two previous occasions of his application. Refund of the fee paid was arranged.

General

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

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

Kalgoorlie, Norseman, Ravensthorpe.

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

Mines Regulation Act, 1946-61.

Examination for Mine Manager's Certificate of Competency.

1st Class.

MINING LAW.

April, 1966.

Attempt Seven (7) questions from Section A.

Attempt Three (3) questions from Section B.

Time Allowed—Three (3) hours.

Candidates should note:—

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

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

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

SECTION A.

(Mines Regulation Act and Regulations).

Attempt Seven (7) questions from this section.

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

Marks allowed are Ten (10) per question.

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

1. (a) Approaching areas where there may be a dangerous accumulation of water.
   (b) When may the underground compressed air supply be cut off?
2. Winzes.
3. Examination of Safety hooks.
   (b) Examination of underground locomotives.
4. (a) Recharging holes previously fired.
   (b) Tests regarding Safety fuse.
   (c) Firing warning.
5. Safety belts and ropes.
6. (a) Ventilating machines.
   (b) Ventilation plans.
7. (a) Action of a Manager on assuming control of a mine.
   (b) Responsibility of a Manager with regard to the Mines Regulation Act and Regulations.
   (c) Inspection of Mine by the Manager.
8. Age requirements of the following:
   (a) Boys employed underground.
   (b) Boys using explosives.
   (c) Hoist driver.
   (d) Braceman.
   (e) Underground Manager.
9. (a) Signals to be used when firing in a shaft sink.
   (b) Obtaining a Hoist Driver's Certificate.
10. Magazines in Mines.

Section B.

(Mining Act and Regulations.)

Attempt Three (3) questions from this section.

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

Marks allowed are Ten (10) per question.

11. Two adjoining leases are connected underground, but are held by different lessees. The first lessee is keeping both properties drained by using his own pumping machinery. If the second lessee refuses to contribute to the cost, can he be compelled to contribute and, if so, how and to what extent?
12. (a) An application for a Lease has been submitted in accordance with the requirements of the Mining Act. What rights does this immedately confer on the applicant?
    (b) Assuming that the rent (if any) is paid regularly and that the required labour conditions are observed, how long can the following be held?
        Prospecting Area.
        Gold Mining Lease.
        Mineral Claim.
        Mineral Lease.
13. (a) The approval of the application for a lease confers certain rights on the lessee. How, if at all, does a Gold Mining Lease differ in this regard from a Mineral Lease?

(b) What are the differences, if any, between the following:
   (i) Tailings Lease?
   (ii) License to treat tailings?

14. (a) How many men must be engaged *bona fide working* to fulfill labour conditions on:—
   (i) A Gold Mining Lease?
   (ii) A Mineral Claim?
   (iii) A Mineral Lease?

(b) Under what conditions may leases, other than Coal Mining Leases, be amalgamated and what labour is required to work the leases which are amalgamated?

15. (a) What Crown Lands shall be exempt from occupation by the holder of a Miner's Right?

(b) Under what conditions may a miner obtain a new Miner's Right which shall be effective from the date of expiration of the old one without payment of other than the normal fee?

Western Australia

Mines Regulation Act, 1946-61

Examination for Certificate of Competency as Underground Supervisor

MINING

September, 1966

Time Allowed Three (3) Hours

Attempt Six (6) Questions Only

Read the Examination Paper Carefully

Answers Must be Written in Ink

Candidates should illustrate with sketches where possible.

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

1. You are in charge of men carrying out minor repairs in the sky shaft over a shaft which is 1000 feet deep. During the repair operations a 24 inch Stillson wrench is accidentally dropped into the shaft. When the repairs have been completed, it is found that a wooden plank measuring 4' x 9" x 2" is missing and it is thought that this also may have fallen into the shaft.
   Explain how you would proceed with an examination of the shaft to ensure safety and to recover the missing equipment.

2. Describe fully the precautions you would take for safe working when:—
   (a) Timbering a leading stope which has a weak hanging wall.

   OR

   (b) Repairing a steel grizzly over an ore pass.

3. Describe in detail, one method of stoping an orebody. Give sketches and explain why this method was chosen.

4. Draw sketches giving details of ventilation and access in one 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 flat pillar supported stope which has advanced 80 feet from the access level.

   Sketches should cover stopes at least 150 feet long.

5. Explain in detail your procedure in boring, charging and firing any two of the following:—
   (a) A drive face using AN/FO and safety fuse.
   (b) A rock pillar in a flat stope using AN/FO and safety fuse.
   (c) A rise 50 feet up, using AN/FO and electric detonators.
   (d) A mill hole draw point which has become blocked with large solid rocks.

6. Explain in detail what, in your opinion are the safety precautions and general safe practices to be always taken and followed by platmen and skipmen, to ensure safety to themselves, the mine personnel, the shaft and haulage appliances.

7. Write a summary on:—
   (a) The safe use of Battery operated locomotives underground;

   OR

   (b) The safe use of Air operated mechanical loaders underground.

8. Write a summary on:—
   (a) The safe storage, handling and use of Nitro-glycerine explosives underground;

   OR

   (b) The safe storage, handling and use of AN/FO underground.

Western Australia

Mines Regulation Act, 1946-61

Examination for Certificate of Competency as Underground Supervisor

MINING LAW

September, 1966

Time Allowed Two (2) Hours

Attempt Twelve (12) Questions

Read the Examination Paper Carefully

Answers Must be Written in Ink

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

1. Cover overhead for cages.
2. Raising or lowering tools or equipment in a shaft.
3. Ladders in shafts.
4. Protection of men working in a shrink stope.
5. Place where a serious accident has occured.
6. Who may fire electrically?
7. Misfires when using safety fuse.
8. Testing of safety fuse.
9. Rises in Mines.
10. Return airways.
11. Stagnant water underground.
12. Winzes—three safety precautions.
13. What is necessary before a person may take charge of a locomotive underground?
14. Method of firing when electric blasting is not in use.
15. Roads used by locomotives.
16. Stoppings and doors.
17. Testing winding engines after repairs.
18. Times of blasting.

Index to State Mining Engineer's Annual Report for 1966

DIVISION III

Report of the Superintendent of State Batteries—1966

Under Secretary for Mines.

For the information of the Hon. Minister for Mines, I submit my report on the operations of the State Batteries for the year ending 31st December, 1966.

Crushing Gold Ores.

One 20 head, five 10 head, and eight 5 head mills crushed 29,422¼ tons of ore made up of 348 separate parcels, an average of 84.55 tons per parcel. The bullion produced amount to 15,260 ozs. which is estimated to contain 12,932 ozs. of fine gold, equal to 8 dwts. 19 grs. of gold per ton of ore.

The average value of the ore after amalgamation, but before cyanidation was 3 dwts. 6 gr. Thus the average head value of the ore was 12 dwts. 1 grs. which is 3 dwts. 19 grs. more than the previous year's average.

A total of 1,033½ tons of tin, tungsten, and tantalite-columbite ore was also crushed at the plants that usually crush mainly gold ores. The average cost for crushing the 30,455¾ tons was $10.11 per ton, compared with 1965 when 41,928 tons were crushed at a cost of $7.85 per ton.

Cyaniding.

Eight plants treated 16,642 tons of tailings from amalgamation for a production of 2,365 fine ozs. of gold worth $74,166. The average content was 3 dwts. 19 grs. before cyanidation, while the residue after treatment averaged 23 grs. The theoretical extraction was, therefore, 74.4%. The actual extraction was 74.6%.

The cost of cyaniding was $5.92 per ton, almost the same as the previous year, when 15,705 tons were treated at a cost of $5.93 per ton.

Treatment of Ores other than Gold.

Lead Ores.—During the year the Northampton State Battery crushed 5,399¾ tons of lead ore with an estimated average content of 14.15% lead. There were 24 separate parcels, giving an average of 225 tons of ore per parcel.

A total of 843.53 tons of concentrates was produced. The concentrates averaged 74.25% lead giving an estimated content of 626.35 tons of lead in concentrates.

4,556 tons of tailings were discarded. These had an average content of 3.02% lead, giving a total of 137.76 tons of lead discarded in tailings.

The recovery of lead in the concentrates was 81.97% of the lead in the ore delivered to the plant.

The cost of operating the Northampton State Battery, including administration, was $33,518.97 being $6.21 per ton of ore crushed. Revenue received was $10,803.05 being $2.00 per ton. The corresponding figures for 1965 when 7,231¾ tons of ore were crushed, were operating cost $37,028.12, $5.12 per ton, and revenue $15,251.50, $2.01 per ton.

Tin Ore.—The Cue Battery crushed 8 tons of ore for ¾ cwt. of concentrates, the Marble Bar Battery crushed 552¼ tons of ore for 4 ton 10 cwt. of concentrates, and the Norseman Battery 444¾ tons of ore for 2 tons 18 cwt. of concentrates. The total value of these concentrates was $16,971.00.

Tungsten Ore.—The Norseman Battery crushed 7¾ tons of ore for 9 cwt. of concentrates valued at $771.00.

Columbite Ore.—The Marvel Loch Battery crushed 20¾ tons of ore for 1½ cwt. of concentrates valued at $605.00.

Agriculture Copper Ore.—No treatment for the year.

Value of Production.

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

GOLD

	1966	Grand Total
	$	$
Par Production—		
Crushing	109,869	17,947,891
Cyanidation	20,347	4,408,609
Gold Premium—		
Crushing	294,277	11,877,327
Cyanidation	53,820	3,255,716
Open Market Premium—		
Crushing	1,861	69,433
Cyanidation	340	22,264
Total Gold Production	480,514	37,581,240

OTHER ORES REALISED

Tin—	$	$
Ores	16,971	212,903
Residues	*Nil*	1,144
Tungsten Concentrates	771	38,471
Agricultural Copper Ore	*Nil*	11,932
Lead Concentrates	157,627	1,053,297
Tantalite—Columbite Concentrates	605	26,505
Total Other Ores	175,974	1,344,252
Grand Total	656,488	38,925,492

FINANCIAL

	Tons	Expenditure	Receipts	Loss
		$	$	$
Crushing (Gold Mills)....	30,455¾	307,883	29,478	278,405
Crushing (Northampton)	5,399¾	33,519	10,803	22,716
Cyaniding	16,642	98,587	32,320	66,267
	....	439,989	72,601	367,388

The loss of $367,388 is a decrease of $11,360 on the previous year. It does not include depreciation and interest on capital.

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

		$
Coolgardie	Cyanide Plant	7,613.30
Cue	Cyanide Plant	27,777.25
Lake Darlot	Cyanide Plant	310.83
Marble Bar	Cyanide Plant	759.22
Meekatharra	Water Supply	3,115.61
Paynes Find	Battery Reconstruction	348.90
Portable Welder	....	6.00
		39,931.11

Cartage Subsidies.

	Tons	Cost
Ore carted to State Plants	10,442¾	$14,202

Comparative Figures for the last three years are:—

Year	State Plants				Private Plants		
	Tons Crushed	Tons Sub-sidised	Per cent. Sub-sidised	Cost	Tons Sub-sidised	Cost	Total Cost
				$		$	$
1964....	47,010½	14,160	30·10	14,428	*Nil*	*Nil*	14.428
1965....	49,159¾	10,134	20·60	11,788	*Nil*	*Nil*	11,788
1966....	35,855½	10,442¾	29·12	14,202	*Nil*	*Nil*	14,202

During the year, to assist prospectors carting ore over longer distances to State Batteries, the maximum cartage subsidy was increased from $1.25 to $2.50 per ton.

Administrative.

Expenditure amounted to $57,929.54 equivalent to $1.10 per ton of ore crushed and cyanided, compared with an expediture of $56,683.54, 87c per ton, for 1965.

	1965	1966
	$	$
Salaries	35,190.83	35,058.87
Pay Roll Tax	7,526.46	7,472.19
Workers Compensation	7,197.43	7,538.69
Travelling and Inspection	4,854.82	5,697.63
Sundries	1,914.00	2,162.16
	56,683.54	57,929.54

Staff.

G. Rasmussen was appointed Senior Draftsman in December. He will replace Engineer R. J. Sinclair who will retire in early 1967.

General.

There was a very big decrease in the amount of gold ore crushed, from 41,481 tons in 1965 to 29,422 tons in 1966. The reduced activity in prospecting for and operating small gold mines can be expected under the present conditons of low gold price, easily obtained well paid employment in other occupations, and the interest in prospecting for other minerals. The total expenditure for crushing gold ore was less than in 1965, but because of the reduced tonnage crushed, the cost per ton rose considerably. The considerable difficulty in obtaining and holding suitable men contributed to the higher crushing cost.

The tonnage cyanided, although still low, was a little higher than in 1965. Costs per ton were almost identical. With more mechanical plants now operating, an increase in cyanide treatment is expected in 1967.

Although the Northampton Battery crushed over 5,000 tons of lead ore, the price of lead dropped during the year and the prospects for the coming year are uncertain.

As expected, more tin ore was crushed at both the Marble Bar and Norseman Batteries. A further increase is indicated for 1967.

K. M. PATERSON,
Superintendent State Batteries.

Schedule No. 1.

Number of Parcels Treated, Tons Crushed, Gold Yield. By Amalgamation and Head Value. For the Year Ended 31st December, 1966.

Number of Parcels Treated	Battery	Tons Crushed	Yield by Amalgamation				Amalgamation Tailings Content		Contents of Ore-Fine Gold			
			Bullion		Fine Gold				Total		Per Ton	
			oz.	dwts.	oz.	dwts.	oz.	dwts.			dwts.	grs.
8	Boogardie	427·00	241	11	204	14	40	6	245	0	11	11
62	Coolgardie	3,428·50	2,641	12	2,238	15	682	2	2,920	17	17	1
1	Cue	Smelt	6	5	5	6	....	....	5	6	....	....
79	Kalgoorlie....	5,234·25	5,372	16	4,553	9	667	7	5,220	16	19	13
18	Lake Darlot	2,123·00	991	13	840	8	367	8	1,207	16	11	9
4	Leonora	1,008·00	753	12	638	14	1,076	12	1,715	6	34	1
25	Marble Bar	1,109·50	1,044	12	885	6	433	11	1,318	17	23	19
37	Marvel Loch	1,722.25	883	13	748	18	233	6	982	4	11	9
21	Meekatharra	4,707·50	873	8	740	4	529	0	1,269	4	5	9
29	Menzies	2,594.00	521	13	442	2	183	2	625	4	4	19
6	Norseman	132·00	44	5	37	10	29	5	66	15	10	3
49	Ora Banda	6,574.25	1,743	14	1,477	16	523	14	2,001	10	6	2
2	Sandstone	49·00	39	16	33	14	7	11	41	5	16	20
7	Yarri	313·00	101	1	85	13	14	16	100	9	6	10
348		29,422·25	15,259	11	12,932	9	4,788	0	17,720	9	12	1

Average Tons per Parcel .... 84·55
Average Yield by Amalgamation per ton (Fine Gold) .... 8 dwts. 19 grs.
Average Head Value of Tailings per ton (Fine Gold) .... 3 dwts. 6 grs.

Schedule No. 2.

Details of Extraction Tailings Treatment, 1966.

Battery	Tons Treated	Head Value			Tail Value			Calculated Recovery		Actual Recovery	
		Per Ton		Total content	Per Ton		Total content				
		dwts.	grs.	oz.	dwts.	grs.	oz.	oz.	%	oz.	%
Coolgardie	1,800	3	16	330·50	0	22	83·70	246·80	74·7	249·08	75·4
Kalgoorlie	4,950	2	21	716·60	0	17	179·90	536·70	74·9	535·85	74·8
Lake Darlot	1,170	3	1	178·75	0	22	52·80	125·95	70·5	125·64	70·3
Marble Bar	360	6	10	115·25	1	14	28·50	86·75	75·3	87·49	75·9
Marvel Loch	1,202	5	12	329·90	1	12	91·45	238·45	72·3	235·32	71·3
Meekatharra	3,240	3	20	619·45	0	23	155·75	463·70	74·8	476·68	77·0
Norseman....	1,160	3	6	188·10	0	23	54·55	133·55	71·0	130·50	69·4
Ora Banda	2,760	5	0	690·30	1	5	166·05	524·25	75·9	524·68	76·0
Total	16,642	3	19	3,168·85	0	23	812·70	2,356·15	74·4	2,365·24	74·6

Schedule No. 3.

Direct Purchase of Tailings.

Year Ended 31st December, 1966.

Battery	Tons of Tailings Purchased	Initial Payment to $28 per Fine oz.
		$
Boogardie	83.50	180.54
Coolgardie	1,926.00	7,034.60
Cue	36.50	9.58
Kalgoorlie	1,126.00	6,124.99
Lake Darlot	1,356.50	2,931.02
Leonora	289.50	547.49
Marble Bar	715.50	6,046.24
Marvel Loch	507.25	2,205.32
Meekatharra	1,118.00	3,684.41
Menzies	307.50	610.31
Norseman	107.75	464.99
Ora Banda	1,274.25	7,234.07
Sandstone	174.75	219.79
Yarri	13.50	96.87
	9,036.50	37,390.22

Schedule No. 4.

Statement of Receipts and Expenditure.
For the Year Ended 31st December, 1966.
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
		$	$	$	$	$	$	$	$	$	$	$	$	$
Boogardie	427	2,458·27	1,591·23	435·32	4,484·82	10·50	1,254·25	771·19	6,510·26	15·24	418·05	0·98	....	6,092·21
Coolgardie	3,428½	7,403.96	11,881·07	3,953·85	23,238·88	6·78	5,417·82	6,622·02	35,278·72	10·29	2,947·58	0·85	....	32,331·14
Cue	8	4,168·68	1,781·30	1,284·21	7,234·19	904·27	4,952·43	869·33	13,055·95	1,631·99	18·02	2·25	....	13,037·93
Kalgoorlie	5,234¼	9,938·10	14,181·64	8,138·66	32,258·40	6·16	9,611·20	8,015·36	49,884·96	9·53	5,323·11	1·07	....	44,561·85
Lake Darlot	2,123	4,335·82	6,658·67	1,868·43	12,862·92	6·06	3,981·80	3,616·91	20,461·63	9·64	1,855·92	0·87	....	18,605·71
Laverton	....	....	324·00	41·16	365·16	....	39·30	74·65	479·11	....	318·49	....	....	160·62
Leonora	1,008	3,772·10	4,884·19	1,748·81	10,405·10	10·32	2,646·13	2,488·37	15,539·60	15·42	1,674·78	1·66	....	13,864·82
Marble Bar	1,661¾	8,295·07	8,242·27	3,020·61	19,557·95	11·76	6,900·46	3,701·19	30·159,60	18·14	2,352·48	1·41	....	27,807·12
Marvel Loch	1,743	5,888·08	7,534·11	2,912·47	16,334·66	9·37	2,239·39	2,447·06	21,021·11	12·06	1,907·66	1·09	....	19,113·45
Meekatharra	4,707½	6,852·90	10,135·68	3,992·73	20,981·31	4·88	7,002·84	6,575·25	34,559·40	7·12	3,438·70	0·73	....	31,120·70
Menzies	2,594	4,182·47	8,033·73	2,337·15	14,553·35	5·61	1,869·61	3,741·50	20,164·46	7·77	2,604·33	1·00	....	17,560·13
Norseman	584½	3,268·51	3,926·19	1,268·27	8,462·97	14·48	1,045·21	1,405·51	10,913·69	18·67	1,148·31	1·96	....	9,765·38
Nullagine	....	....	842·63	94·68	937·31	....	216·65	307·00	1,460·96	....	....	....	....	1,460·96
Ora Banda	6,574¼	5,964·53	10,467·94	4,258·97	20,691·44	3·14	8,473·29	7,038·89	36,203·62	5·51	4,904·83	0·75	....	31,298·79
Paynes Find	....	....	444·00	....	444·00	....	185·90	39·17	669·07	....	....	....	....	669·07
Peak Hill	....	....	335·46	252·42	587·88	....	60·62	56·49	704·99	....	....	....	....	704·99
Sandstone	49	1,056·53	376·96	50·35	1,483·84	32·34	562·66	220·59	2,267·09	46·26	52·00	1·06	....	2,215·09
Yarri	313	845·09	2,412·23	1,700·66	4,957·98	15·84	2,533·95	1,056·86	8,548·79	27·31	465·35	1·49	....	8,083·44
Head Office	....	....	....	....	....	....	....	....	....	....	48·56	....	48·56	....
Sub-Total	30,455¾	68,430·11	94,053·30	37,358·75	199,842·16	6·55	58,993·51	49,047·34	307,883·01	10·11	29,478·17	0·97	48·56	278,453·40
Northampton	5,399¾	9,088·82	6,848·53	4,050·24	19,987·59	3·70	6,090·96	7,440·42	33,518·97	6·21	10,803·05	2·00	....	22,715·92
Total	35,855½	77,518.93	100,901·83	41,408·99	219,829·75	6·10	65,084·47	56,487·76	341,401·98	9·52	40,281·22	1·12	48·56	301,169·32

NET LOSS : $301,120·76

Schedule No. 5.
Receipts and Expenditure, 1966.
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
		$	$	$	$	$	$	$	$	$	$	$		$
Coolgardie	1,800	1,407.02	3,847.07	2,441.18	7,695.27	4.28	1,523.32	3,279.20	12,497.79	6.94	3,426.44	1.90	....	9,071.35
Cue	....	91.73	475.81	....	567.54	....	....	....	567.54	....	....	....	....	567.54
Kalgoorlie	4,950	5,133.02	8,169.08	5,630.00	18,932.10	3.82	3,660.12	6,991.23	29,583.45	5.98	11,450.48	2.31	....	18,132.97
Lake Darlot	1,170	880.68	1,793.47	1,007.84	3,681.99	3.15	610.98	1,515.26	5,808.23	4.96	2,107.26	1.80	....	3,700.97
Marble Bar	360	589.47	1,317.59	478.09	2,385.15	6.62	576.56	661.76	3,623.47	10.07	770.07	2.14	....	2,853.40
Marvel Loch	1,202	839.51	2,181.09	1,009.07	4,029.67	3.35	21.83	1,486.87	5,538.37	4.61	3,474.84	2.89	....	2,063.53
Meekatharra	3,240	676.86	8,301.73	4,664.10	13,642.69	4.21	936.51	3,753.48	18,332.68	5.66	8,337.28	2.57	....	9,995.40
Norseman	1,160	1,333.90	1,913.50	1,776.23	5,023.63	4.33	371.48	1,670.53	7,065.64	6.09	2,007.29	1.73	....	5,058.35
Ora Banda	2,760	2,014.92	5,524.23	3,853.56	11,392.71	4.13	145.77	4,032.18	15,570.66	5.64	5,066.48	1.84	....	10,504.18
Totals	16,642	12,967.11	33,523.57	20,860.07	67,350.75	4.05	7,846.57	23,390.51	98,587.83	5.92	36,640.14	2.20	....	61,947.69

Total Receipts	36,640.14		
Interest Paid to Treasury	4,320.00		$4,320.00
	32,320.14	Gross Loss	$66,267.69

STATE BATTERIES.
TRADING AND PROFIT AND LOSS ACCOUNT.
FOR THE YEAR ENDED 31st DECEMBER, 1966.

1965		1966	
$		$	$
	Trading Costs—		
225,822	Wages	224,911	
75,306	Stores	62,269	
78,712	Repairs, Renewals and Battery Spares	72,935	
83,938	General Expenses and Administration	84,194	
463,778			444,309
	Earnings—		
85,030	Milling and Cyaniding Charges		76,921
378,748	Operating Loss for the Year		367,388
	Other Charges—		
55,886	Interest on Capital	57,692	
27,524	Depreciation	26,719	
5,836	Superannuation—Employers Share	5,774	
			90,185
89,246			
			$457,573
$467,994	Total Loss for the Year		

STATE BATTERIES.
BALANCE SHEET.
AS AT 31st DECEMBER, 1966.

31st December, 1965	Funds Employed		31st December, 1966	
$			$	$
	Capital—			
1,338,106	Provided from General Loan Fund		1,378,037	
274,408	Provided from Consolidated Revenue Fund		274,409	
1,612,514				1,652,446
	Reserves—			
57,244	Commonwealth Grant—Assistance to Goldmining Industry		57,244	
27,572	Commonwealth Grant—Assistance to Metalliferous Mining		27,572	
84,816				84,816
	Liability to Treasurer—			
2,213,418	Interest on Capital			2,271,110
30,000	Advance for Purchase of Tailings			30,000
	Other Funds—			
4,504,420	Provided from Consolidated Revenue Fund (Excess of payment over collections)			4,879,994
8,445,168				8,918,366
	Deduct—			
	Profit and Loss :			
7,526,152	Loss at Commencement of Year	7,994,146		
	Plus Stores Adjustment	107,988		
			8,102,134	
467,994	Loss for Year		457,573	
7,994,146	Total Loss from Inception			8,559,707
$451,002				$358,659
	Employment of Funds			
	Fixed Assets—			
1,601,332	Plant, Buildings and Equipment		1,641,263	
1,369,206	*Less* Depreciation		1,395,925	
232,126				245,338
	Current Assets—			
7,574	Debtors		9,937	
175,294	Stores	179,532		
	Less Adjustment	107,988		
			71,544	
8,114	Battery Spares		8,462	
	Purchase of Tailings :			
7,764	Treasury Trust Account		1,833	
121,652	Tailings not treated		126,950	
16,664	Estimated Gold Premium		17,277	
337,062				236,003
569,188	Total Assets			481,341
	Deduct—			
	Current Liabilities :			
16,702	Creditors		15,465	
81,384	Liability to Treasurer (Superannuation—Employers Share)		87,157	
	Purchase of Tailings :			
3,416	Creditors		2,783	
16,664	Estimated Premium Due		17,277	
118,166				122,682
$451,022				$358,659

DIVISION IV

Annual Report of the Geological Survey Branch of the Mines Department for the Year 1966

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DIVISION IV

Annual Report of the Geological Survey Branch of the Mines Department for the Year 1966

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 of Western Australia for the year 1966, together with some of the reports on investigations made for departmental purposes.

ORGANIZATION

Despite the shortage of geologists in Australia, the Geological Survey was fortunate in filling all vacancies, except for that of a geophysicist, in the early part of the year. However, later resignations have created vacancies, which are proving difficult to fill with competent officers.

The recommendations made last year for additional staff in the Sedimentary (Oil) Division, to keep abreast of the expanded company activity and general exploration for oil, are still under consideration and only one position for an additional senior geologist has been approved. It is hoped to make an appointment to this position early in the new year.

Because of the unprecedented activity in metalliferous mineral exploration, particularly for nickel and base metals, and the continued expansion in the oil search activities, the services provided by the Geological Survey were in great demand, particularly the reference library, the provision of information on known mineral occurrences, on localities, verbal discussions on the progress and results of geological mapping, and general advice on mineral potential.

STAFF

PROFESSIONAL

Appointments :

Name	Position	Effective Date
J. L. Baxter, B.Sc. (Hons.)	Geologist, Grade 2	5/1/66
J. J. G. Doepel, B.Sc. (Hons.)	Geologist, Grade 2	5/1/66
A. E. Cockbain, B.Sc. (Hons.), Ph.D.	Palaeontologist	6/1/66
J. H. Currie, B.Sc.	Geologist, Grade 2	18/1/66
R. Peers, B.Sc. (Hons.)	Geologist, Grade 2	21/2/66
P. C. Muhling, B.Sc. (Hons.)	Geologist, Grade 2	14/3/66
L. N. Wall, M.Sc., D.I.C.	Geologist, Grade 2	21/9/66

Resignations :

E. E. Swarbrick	Geologist, Grade 2	21/1/66
I. Gemuts	Geologist, Grade 2	25/2/66
J. H. Currie	Geologist, Grade 2	11/8/66
R. Milbourne	Geologist, Grade 2	31/8/66

Promotions :

K. H. Morgan	Geologist, Grade 1	1/10/65
L. E. de la Hunty	Supervising Geologist	10/1/66
J. G. Blockley	Geologist, Grade 1	14/1/66
J. L. Daniels	Senior Geologist	8/3/66
M. J. B. Kriewaldt	Geologist, Grade 1	24/6/66

CLERICAL AND GENERAL

Appointments :

R. A. H. Stevenson	Clerk	6/1/66
B. Kozak	Library Assistant (Temp.)	21/2/66
B. Aleksandrow	Laboratory Assistant	18/4/66
S. M. Fawcett, M.A.	Library Assistant	9/5/66
V. D. Thornber	General Assistant	27/6/66

Resignations :

V. M. Marshall	Library Assistant	4/2/66
S. C. Crew	Clerk	18/2/66
P. M. Bryant	Laboratory Assistant	18/2/66
B. Kozak	Library Assistant (Temp.)	9/5/66
R. A. Taylor	Geological Assistant	20/5/66

Transfer :

D. H. Johnston	Clerk to Education Department	30/4/66

The total establishment for the Geological Survey is now 40 professional, 6 clerical, and 10 general officers.

ACCOMMODATION

The Branch continues to occupy five separate small buildings in three adjoining streets. At present there is no definite proposal to alleviate this position. The records section is working in cramped and poor accommodation, while the library is suffering from the lack of storage space and reading space for visitors.

Plans are being prepared for the expansion of the core library at Dianella.

The expansion of the Government Records Repository has limited the space for the Geological Survey's vehicle park and general store. Eventually it will be necessary to move this store and vehicle park, and, as there is no adjacent land available, another site will have to be found.

OPERATIONS

HYDROLOGY AND ENGINEERING GEOLOGY DIVISION

E. P. D. O'Driscoll (Chief Hydrogeologist), K. Berliat, F. R. Gordon, T. T. Bestow (Senior Geologists), J. D. Wyatt, D. H. Probert, K. H. Morgan, J. R. Passmore, P. Whincup, R. A. Farbridge, C. C. Sanders, L. N. Wall, and A. D. Allen (on leave without pay at London University).

Hydrology

Exploratory drilling was completed in the Yule River area for the Port Hedland town water supply, where sufficient water for the immediate needs of the township was proved.

Drilling continued in the Arrowsmith River area to determine the extent of the water province that is being used for the Morawa town water supply.

Drilling on the Mandurah hydrological investigation and on the Albany town water supply project continued, while successful drilling programmes for town water supplies were completed near Jurien Bay and Coomberdale.

On the long term programme of deep drilling in the Perth Basin, a line of holes across the basin near Gingin was completed and a new line was commenced near Busselton.

The regional investigation of the Esperance area continued, together with experimental work on the application of geophysics to the search for groundwater. The groundwater resources of a portion of the Kimberley was assessed in association with regional mapping, and a groundwater reconnaissance survey of the Pilbara area was made.

For the Metropolitan Water Board the investigation of the Gnangara Lake area was continued on a restricted scale, and a preliminary investigation was made on three small catchments in the Darling Range to ascertain if they were suitable for detailed catchment management studies.

Field surveys on Government projects were made also of the West Mugadong district, Goodlands district, Miami area, Exmouth, Dwellingup, Jerdacuttup, Bindi Bindi, Latham, and Una townships, and for Pippingarra native reserve and Condingup, Waroona, Wannamal, and Mogumber schools. In all, 26 field inspections were made for other Government Departments and 75 for private landholders.

Engineering Geology

A comprehensive programme of site exploration was continued at the Kennedy Range dam site, which included detailed and regional mapping and the planning and supervision of percussion and Gemco auger drilling programmes.

Investigations were carried out on a proposed dam storage for the water supply for Wyndham at Moochalabra Creek, which included detailed mapping, supervision of diamond drilling, and the location of supplies of impervious core material, filter sand, and rockfill.

An erosion problem at the Bandicoot Bar Diversion Dam was appraised and remedial works, now completed, were suggested. The geology of the Ord River dam site was revised and geological contract documents and plans were completed.

A reconnaissance survey was made of eight possible dam sites in the Pilbara region.

SEDIMENTARY (OIL) DIVISION

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

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

P. E. Playford accompanied the Honourable Minister for Mines and the Assistant Under Secretary on a three-months visit to the United States, Canada, Europe, and North Africa to study petroleum exploration, production, and legislation in those countries.

In the Perth Basin, mapping was continued on parts of the Perth, Pinjarra, and Geraldton 1:250,000 Sheets. Regional mapping in the Eucla Basin has been completed as far as the South Australian border.

A drilling programme for ilmenite in the Pleistocene beach sands of the Yoganup area in the southern Perth Basin was planned and supervised.

REGIONAL GEOLOGY DIVISION

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

Eastern Goldfields Area

Field work was continued on the Kurnalpi 1:250,000 Sheet, where valuable stratigraphic information has been gained on the Archaean. Advice was supplied to pastoralists on hydrology and to prospectors on mineral occurrences and local geology. A nickel prospect was discovered at Lake Rebecca, in the course of systematic geological mapping on the Kurnalpi Sheet.

Blackstone Area

Mapping commenced in the Blackstone area in the extreme eastern portion of the State. Field work on the Scott 1:250,000 Sheet was completed and the Cooper Sheet has been started. The work has also provided a better understanding of the distribution of the nickeliferous laterites, and the younger deposits that are the main source of water in the area.

General

An area along the Darling Scarp on the Pinjarra 1:250,000 Sheet was mapped. Visits were made to the Esperance and Cue—Mount Magnet regions to co-ordinate the results of geological mapping of other divisions into the general pattern of the Precambrian of the State.

The compilation of maps from field work completed in previous field seasons, continued.

Samples were collected for a joint programme of rock age determinations with members of the Australian National University.

The programme of geological mapping at 1:250,000 scale to the end of 1966 is shown on Figure 1.

MINERAL RESOURCES DIVISION

L. E. de la Hunty (Supervising Geologist), J. Sofoulis (Senior Geologist), J. G. Blockley, P. C. Muhling, J. Baxter, and R. S. Chaturvedi (Colombo Plan Fellow, temporarily attached from University of W.A.).

Kimberley Division

Appraisals were made of the mineral deposits of the Yampi, Lennard River, and Charnley Sheet areas, in conjunction with the regional mapping programme of that area conducted jointly with the Bureau of Mineral Resources. Reports were compiled on the bauxite potential of the northern part of the Kimberley Division, and on copper and mica deposits in the western part.

North-West Division

Field work was completed on the comprehensive survey of the blue asbestos deposits of the Hamersley Range area, and compilation of a bulletin was commenced. Several field excursions were arranged for visiting geologists to inspect the iron deposits with black shales, fossils, and pseudo-fossils localities and natural sections of the Precambrian succession in the Hamersley Range area.

The Robertson 1:250,000 Geological Sheet was compiled.

Field work was continued on the mineral resources, regional geology, and hydrology of the Cue 1:250,000 Sheet.

Miscellaneous inspections were made in connection with gold, copper, water, and a reported meteorite crater.

South-West Division

A diamond drilling programme was carried out at the Geraldine lead mine, near Galena, and field inspections were made on deposits of ilmenite and bauxite.

COMMON SERVICES DIVISION

Petrology (A. F. Trendall and R. Peers)

During the year, 29 file reports were written dealing with collections of between one and 37 rocks. The reports were for all Divisions of the Survey, other Government departments, and members of the public. A total of 1,528 thin-sections and 23 polished sections were prepared by the technical staff. An important part of the work of this section is to advise and assist geologists of all Divisions, particularly those engaged on regional mapping, in their own petrological treatment of their rocks. The appointment of an assistant petrologist has reduced considerably the backlog of petrological work.

Dr. Trendall assumed responsibility for the supervision of the special study of blue asbestos in the Hamersley Range area initiated in 1964. He spent six weeks in the field in the Hamersley area in connection with this work, and later 11 weeks were devoted to a tour of Precambrian iron formations in the Lake Superior area of the United States, the Labrador trough in Canada, and the Cape Province and Transvaal asbestos-producing areas of South Africa. The comparative knowledge thus gained of the iron formations of the Hamersley Group will ensure a definite assessment of the economic potential of blue asbestos in Western Australia during 1967. An informally circulated list of work on Western Australian iron formations is materially contributing to the international co-ordination of iron formation studies.

During the year Dr. Trendall was invited to join the Australian National Committee for the Upper Mantle Project, an international programme of geological and geophysical research. The Committee is organizing on a national basis an intensive study of the structure and development of the ancient rocks of the southwestern part of this State.

Chemical and mineralogical support for many petrological studies from the Government Chemical Laboratories must again be gratefully acknowledged.

Palaeontology (A. E. Cockbain and B. S. Ingram)

During the year, 68 file reports were written, many of which involved the palynology of Mesozoic samples sent in by the Hydrology Division. Palynological samples from bores in the Arrowsmith River and Gingin Brook areas have yielded useful stratigraphical and palaeontological information. Other work has included studies of the Permian and Cretaceous of the Kennedy Range—Gascoyne Junction area, the Tertiary of North West Cape, the Permian of the Irwin River region, and the Tertiary of the Albany—Esperance area.

In addition to these small-scale studies, the palaeontology laboratory is engaged on two major projects: (1) a palynological zonation of the Upper Jurassic—Lower Cretaceous sediments of the Yarragadee Formation in the northern Perth Basin and (2) systematic and stratigraphical palaeontology of Foraminifera and Bryozoa from the Eucla Basin.

The palaeontology laboratory is now able to handle most requests involving palynology and micropalaeontology, and whilst some macro-invertebrate groups are identified in the laboratory, other material is sent away to experts. We are especially grateful to Mr. B. E. Balme (University of Western Australia) and Mr. G. W. Kendrick (Western Australian Museum) for much helpful advice. With this expansion of the laboratory, it has been necessary to start a punched card index to the fossil samples catalogued under G.S.W.A. " F " numbers.

Geophysics (D. L. Rowston)

Geophysical work during the year encompassed well-logging and routine laboratory services, and a variety of field investigations.

Although the number of well-logging operations decreased to 35 the total footage logged increased substantially to 38,000 feet. Salinity determinations were made on about 600 samples. An experimental survey to test the applicability of geophysical methods to groundwater search was made in the Esperance area. Resistivity, electromagnetic, magnetic, and self-potential methods were used on several localities, where special problems of groundwater concentration and salinity were recognised. A number of bores, sited to test geophysical anomalies and to provide information for their interpretation, are being drilled.

A radiometric survey was made along an ancient strandline near Busselton to supplement a geological study of beach sand deposits and reserves of ilmenite, monazite, and zircon.

As a result of the increased activity in base metals exploration, numerous enquiries on geophysical prospecting methods and techniques were received. Minor surveys were made to demonstrate and test the efficacy of various methods in particular enviroments.

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

Technical editing of reports, maps and plans for publication, and the supervision of publications, continues to be the major function of this section. Twenty one Records were produced.

Requests for information by the staff, mining companies, consultants, and general public continue to increase but not at the same rate as in the previous year.

The operations of the library were hampered in the early part of the year by staff resignation. The library loans to staff increased to 1,683, while loans to the public and other libraries totalled 257. Requisitions raised on the Drafting Branch for drawing, copying, and photographing services totalled 601.

At the core library considerable time has been spent reducing the size of sludge samples but despite this reduction of bulk, little storage space remains for current material.

ACTIVITIES OF THE COMMONWEALTH BUREAU OF MINERAL RESOURCES

The Bureau of Mineral Resources carried out both geophysical and geological work in this State during 1966. The projects included:

1. Regional geological mapping of the Yampi, Charnley, and Lennard River 1:250,000 Sheets in the Kimberley Division, jointly with the Geological Survey of Western Australia.

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

3. Aeromagnetic survey (DC3 aircraft) of the Leonora and Laverton 1:250,000 Sheets.

PROGRAMME FOR 1967

HYDROLOGY AND ENGINEERING DIVISION

Hydrology

1. Continuation of the hydrological survey of the Perth Basin including deep drilling.
2. Hydrogeological investigation and exploratory drilling for groundwater in the following areas:
   (a) Mandurah—Pinjarra
   (b) Gnangara Lake
   (c) Arrowsmith River area
   (d) Albany
   (e) Esperance Plains
   (f) Port Hedland
   (g) Midlands light lands
   (h) Eucla Basin
   (i) Others, as required.
3. Kimberley: hydrological assistance to pastoralists
   (a) bore site selection as required
   (b) regional hydrogeological mapping in conjunction with the Bureau of Mineral Resources.
4. Miscellaneous minor investigations as requested by other departments and the public.

Engineering

1. Kennedy Range Dam Site—supervising of drilling of abutments.
2. Standard Gauge Railway—investigations as requested and detailed mapping of cuttings.
3. Investigations of a dam site either on Fitzroy River or in Pilbara.
4. South Dandalup Dam Site—supervision of drilling.

SEDIMENTARY (OIL) DIVISION

1. Maintain an active interest in the progress of oil exploration in Western Australia.
2. Continuation of the mapping programme in the Perth Basin.
3. Compilation of the geological survey of the Eucla Basin.
4. Miscellaneous investigations as required.

REGIONAL GEOLOGY DIVISION

1. Continuation of mapping in the Eastern Goldfields on the Kurnalpi and Menzies Sheets.
2. Continuation of the regional mapping of the Kimberley Division in conjunction with the Bureau of Mineral Resources.
3. Continuation of mapping in the Eastern Division on the Cooper, Talbot, and Bentley Sheets.

MINERAL RESOURCES DIVISION

1. Completing the regional investigation of the blue asbestos deposits of the Hamersley Range.
2. Continuation of the mineral survey of the Yalgoo and Murchison Goldfields.
3. Miscellaneous investigations as required.

PUBLICATIONS AND RECORDS

Listed below are the six publications issued during the year.

Printing of the two important bulletins on the Hamersley Range Iron Ore and the Devonian Reefs of the Canning Basin has not been completed although submitted over a year ago.

Issued during 1966

Annual Report 1965.

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

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

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

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

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

In Press

Bulletin 117, The Geology and Iron Deposits of the Hamersley Range Area, Western Australia.

Bulletin 118, Devonian Reef Complexes of the Canning Basin, Western Australia.

Mineral Resources of Western Australia.

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

Geological Map of the Pyramid 1:250,000 Sheet (SH/50-7 International Grid) with Explanatory Notes.

In Preparation

Geological maps (1:250,000) with Explanatory Notes, the field work for each having been completed: Turee Creek, Yarraloola, Wyloo, Kalgoorlie, Edmund, Robertson, Scott, and sheets covering the Western Australian portion of the Eucla Basin.

Records Produced

1966/1	Second progress report on the Brockman Iron Formation in the Wittenoom-Yampire area, by A. F. Trendall.
1966/2	The geology of the Ord River Dam and associated works, by F. R. Gordon (RESTRICTED).
1966/3	Stability of the Kellerberrin rock cuts, Standard Gauge Railway, Northam to Merredin, by F. R.
1966/4	An outline of the hydrogeology of Nicholson, Gordon Downs, Flora Valley, Sturt Creek, Ord River, Turner River, and Spring Creek Stations (Vestey's Stations), East Kimberleys, W.A., by A. D. Allen.
1966/5	Geological reconnaissance at Duracks Folly, Kununurra to Ord main dam site road, by F. R. Gordon (RESTRICTED).
1966/6	Not issued.
1966/7	Mt. Krauss diversion dam site, by F. R. Gordon (RESTRICTED).
1966/8	Geological reconnaissance at Moochalabra Creek dam site by F. R. Gordon (RESTRICTED).
1966/9	Barramundi Range dam site, by F. R. Gordon (RESTRICTED).
1966/10	Geophysical investigations for beach sand deposits in the Yoganup area, by D. L. Rowston.
1966/11	Details of clay, loam, kyanite, and shale samples taken during a geological survey of Perth and environs, 1950–51, by L. E. de la Hunty.
1966/12	Details of limestone, bog limestone, and limesand samples taken during a geological survey of Perth and environs, 1950–51, by L. E. de la Hunty.
1966/13	Details of silica sand, diatomite, quartz, and glauconite samples taken during a geological survey of Perth and environs, 1950–51, by L. E. de la Hunty.
1966/14	Drilling for mineral beach sands in the Yoganup area, South-West Division, Western Australia, by G. H. Low (RESTRICTED).
1966/15	Exploratory drilling for underground water, Gingin Brook area, Perth Basin, by C. C. Sanders.
1966/16	The hydrogeology of the Kimberley Plateau, by A. D. Allen.
1966/17	Geological reconnaissance at Macdonald Gorge dam site, by F. R. Gordon.
1966/18	Review of a quarrying operation at Merredin Standard Gauge Rail Project, by F. R. Gordon.
1966/19	South Dandalup upper dam site, results of auger and diamond drilling, by J. D. Wyatt (RESTRICTED).
1966/20	Geological investigation of Moochalabra dam site, by J. D Wyatt.
1966/21	Wells drilled for petroleum exploration in Western Australia by P. E. Playford.

Reports in other publications

Daniels, J. L., 1966, The Proterozoic geology of the North-West Division of Western Australia: Australasian Inst. Mining Metall. Proc. 219, p. 17-26.

Playford, P. E., 1966, Upper Devonian and possible lower Carboniferous reef complexes in the Bonaparte Gulf Basin: Australian Jour. Sci. v. 28, p. 436.

Gellatly, D. C., and Sofoulis, J., 1966, Geology of the Drysdale—Londonderry 1:250,000 Sheet areas SD52/5-9, Western Australia: Australia Bur. Mineral Resources Rec. 1966/55.

Trendall, A. F., 1966, Carbon dioxide in the Precambrian atmosphere: Geochim. et Cosmochim. Acta v. 30, p. 435-437.

Trendall, A. F., 1966, Towards rationalism in Precambrian stratigraphy: Geol. Soc. Australia Jour. v. 13, p. 517-526.

1st February, 1967.

J. H. LORD,
Director,
Geological Survey.

GEOLOGICAL SURVEY OF WESTERN AUSTRALIA

1: 250,000 OR 4 MILE GEOLOGICAL MAPPING

1966

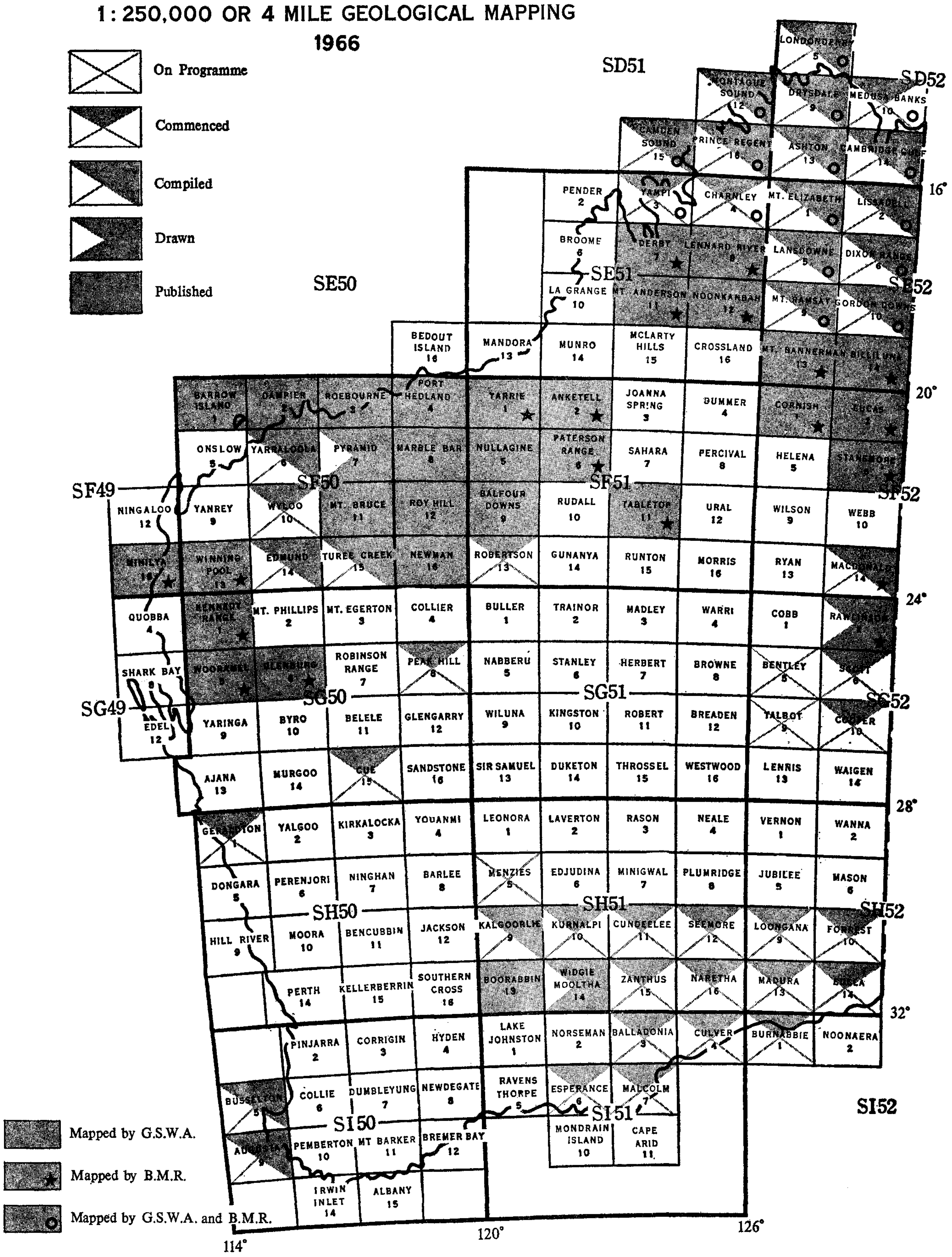


FIGURE 1

AN APPRAISAL OF THE GROUNDWATER CONDITIONS IN THE GOODLANDS AREA

by K. Berliat

INTRODUCTION

Centered about longitude 117°15′ and latitude 30°05′, the Goodlands area is covered by Lands Department lithograph 88/80. The area extends southward from the Emu Proof Fence, and is limited to the east and west by the systems of Lake Moore and Lake de Courcy. The total area is about 500 square miles.

It is a marginal agricultural area under active development, but there are also some long established farms, particularly in the south. The nearest railheads are Kalannie in the south an Dalwallinu and Wubin in the west.

Long term rainfall records are not available, but annual averages are stated to be in the order of 9 to 11 inches. In the last 2 years however, falls appear to have been considerably in excess of these figures.

TOPOGRAPHY, GEOLOGY

Topographically the surface is flat or broadly undulating, and consists of about equal parts of heavy, clayey country and sandplains. Internal drainage is towards the salt lakes in the east and west, but there are no incised channels, and only a few incipient, ill-defined gullies have been developed.

Basement rock is predominantly Archaean granite, sporadically intruded by quartz dykes. Outcrops occur mostly in the form of granite ' rocks ', and occur mainly in the eastern half of the area bordering Lake Moore. Almost everywhere else the basement is obscured by a mantle of decomposed material ranging in thickness from a few feet to about 200 feet.

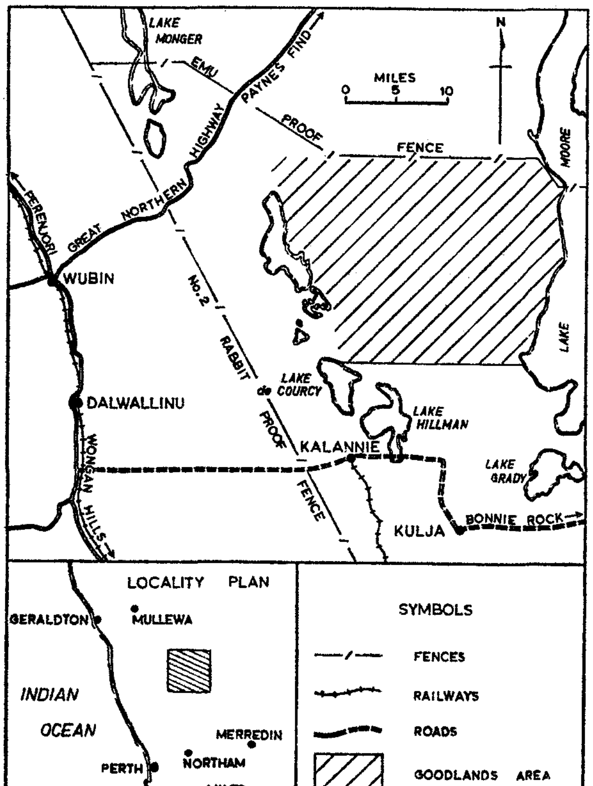


FIGURE 2 · LOCALITY PLAN — GOODLANDS AREA

HYDROLOGY

Three potential sources of groundwater have been recognized.

The superficial weathering profile

This is by far the most important aquifer, and, as it covers practically all of the area, one might be inclined to think that groundwater should readily be available. There are however many factors controlling its occurrence, quality and yield, and to obtain a useful supply these factors must overlap. This is not the rule, but rather the exception. Disregarding all other things it must be kept in mind that precipitation is directly related to the quality and quantity of the groundwater, and in areas receiving falls of less than about 17 inches per annum the groundwater is naturally saline, and the location of usable supplies becomes a matter of difficulty. For such regions of low rainfall the best prospects are where there is concentrated local intake, a factor related to good catchments and therefore dependent upon a well differentiated topographical relief. In the Goodlands area favourable conditions of this nature occur only exceptionally around the margins of some of the major granite outcrops.

Another factor to be considered is the permeability of the weathering profile, which is subject to wide variations both horizontally and vertically. In this respect all the heavy red country has to be eliminated as a source of groundwater. Also, to avoid highly saline water, it is important that the permeable profiles be located in the higher portions of the topography.

The most critical single factor, however, is the thickness of the zone of decomposition, in other words the configuration of the bedrock surface at depth. With the possible exception of high salinity, shallow bedrock is by far the most frequent cause for the great number of unsuccessful bores in the district. It must be understood that the bedrock is not a level surface but has irregularities that are not related to the land surface. Drilling information in the district shows that the bedrock relief can change rapidly, and this is a major cause for the great differences in bore performance over short distances. Economic supplies of groundwater can only accumulate where there is sufficient area and volume for storage, i.e., in bedrock depressions filled with pervious material. Unfortunately it is rarely possible to determine such depressions from surface evidence, and therefore the selection of bore sites in granitic terrain will always be speculative to some degree. The Geological Survey is currently conducting experiments to determine the bedrock relief by geophysical means. If the tests are successful, and if a quick and inexpensive method can be worked out, it will be of very great assistance in areas such as Goodlands.

The solid granite

Solid granite has practically no porosity and the occurrence of water in this rock type depends wholly on joints and fractures. As a rule such openings are sufficiently wide and numerous only if the uppermost part of the massive rock, and drilling should be abandoned if no water has been encountered within a depth of 100 feet. On account of the great irregularity of the spacing of the joints the success of any bore in solid granite is largely a matter of chance, depending on whether the location is a fortunate one with respect to the arrangement of joints. Drilling into granite has not been attempted so far in the Goodlands area, presumably because the special equipment necessary was not available.

The quartz dykes

As in solid granite, successful bores in quartz depend on the presence of joints, and on the extent to which these joints persist and intersect others. Because of their scattered distribution quartz dykes are only of minor importance in the area as a whole, but there are at least two places where they offer promising groundwater prospects. Bore siting, however, is difficult because the outcrop area and the dip of the dykes is seldom ascertainable.

CONCLUSIONS

1. The normal groundwater in the Goodlands area is saline, and useful supplies will only be found under exceptional conditions.

2. Small supplies of domestic water could occur in isolated instances around the periphery of major granite outcrops, provided there is a concentration of run-off, and pervious soil.

3. Possibly between 50% and 75% of the total area has to be eliminated as a source for stock water. This includes all the heavy country and the low-lying, featureless sandplain.

4. High-level sandplain depressions and the long, sandy slopes, characteristic of the area, are worthy of testing by drilling, but success will depend upon a favourable combination of the factors outlined above.

5. From surface evidence alone bore sites cannot be selected with any real degree of assurance. It is possible however to eliminate unprospective areas, and to outline others which are suitable for test drilling.

6. As development progresses, more and more demands will be made on the restricted bodies of usable groundwater, and this could render the salinity problem even more acute. Salinity increases, at least of a temporary nature, could also result from large-scale clearing. In due time, therefore, the groundwater positions in the Goodlands area should be reviewed in this context.

PORT HEDLAND TOWN WATER SUPPLY
HYDROGEOLOGICAL INVESTIGATION OF THE YULE RIVER AREA

by P. Whincup

ABSTRACT

The Yule River alluvial valley, 42 miles west of Port Hedland, has been investigated as a possible groundwater source for the township. Fifty-eight shallow auger holes and thirty-two percussion holes were drilled in an area of 270 square miles.

Three aquifers termed the upper sand, lower sand, and bedrock aquifer were penetrated. Bore yields varied from less than a thousand to about thirteen thousand gallons per hour.

Approximate aquifer coefficients have been determined and used to calculate groundwater flow and recharge to the area. It is estimated that 1·3 million gallons of water per day can be withdrawn from the area without depleting the groundwater held in storage.

INTRODUCTION

Port Hedland is 1,124 miles north of Perth on the North-West Coastal Highway. Its development as the outlet port for Mt. Goldsworthy iron ore has resulted in an increase in population from 1,120 in 1961 to an estimated 5,000 in 1978 when the water requirements of the town will be one million gallons per day. A maximum of 200,000 gallons per day is available from the present pumping field at the Turner River (Farbridge, 1967).

The next nearest groundwater source to the town was considered to be the Yule River area (Allen, 1964) and at the request of the Public Works Department the area has been investigated to determine whether supplies of 800,000 gallons per day are available. Drilling was done between December 1965 and December 1966.

The work and comments of A. D. Allen are gratefully acknowledged.

CLIMATE

The climate may be described as tropical coastal typified by warm, dry winters and hot summers. The average annual rainfall of 11·8 inches (37 year records at Mundabullangana Station) falls mainly between January and March when the average maximum temperature is 94°F and the minimum 74°F. However the rainfall is cyclonic and therefore unreliable, ranging between 1·1 and 28·5 inches annually.

DRILLING PROGRAMME

Initially a rough two-mile grid of boresites was drilled by two Public Works Department 110A Gemco auger drills to delineate with reasonable accuracy the area of good quality water. Deeper percussion holes were then drilled to bedrock on favourable Gemco-drilled sites. Names, numbers, and locations of wells and bores are shown on Plate 1.

Fifty-eight Gemco holes were drilled (including several drilled twice), the maximum depth being about 80 feet. Many were abandoned in some instances before water was cut, when basaltic pebbles and cobbles were encountered at shallower depths.

Thirty-two deeper, six-inch, percussion bores were completed but these include several holes redrilled when difficulties were encountered e.g., 10, 10A, and 10B. The Mines Department drilled 15 bores using two Ruston Bucyrus 22W percussion rigs and the remainder were drilled on contract by Boomerang Boring Co. (12 bores) using two Wabco percussion rigs, and Drillwell Pty. Ltd. (5 bores) using an Ingersoll Rand Drillmaster rockdrill.

PHYSIOGRAPHY

The northerly-flowing Yule River is thought to be a consequent stream incised into the pediplain of the retreating Nullagine Scarp (Ryan, 1966). The pediplain is now evident on the western margin of the drilling area as a high-level sandplain underlain by shallow rock. The Archaean basement rocks occasionally crop out as low-lying hills. In the places the red surface sand has accumulated as east-west trending seif dunes.

Fluviatile deposits form a silty flood plain which covers the drilling area. The deposits thicken and widen northwards towards the coast. Levees and river terraces are well developed along the present river course.

Drilling results and bedrock contours show that the river has changed course several times, and the remnants of an old river terrace can be seen at the surface between Bores 9 and 10. As a rule, however, the old river channels cannot be accurately delineated.

The river bed consists of coarse river sand and gravel which contain several impermanent pools, particularly along the eastern branch. Near the southern margin of the area the river bifurcates. The eastern branch has a wide, well defined channel whereas the western branch has a braided pattern with numerous anabranches.

GEOLOGY

The area falls within the Roebourne 1:250,000 Geological Sheet described by Ryan (1966). Rocks of Quaternary and Archaean age were penetrated in the drilling programme. Possible Tertiary rocks are grouped with the Quaternary.

A cross section through the area is shown on Plate 2.

Quaternary to Recent

The Quaternary to Recent alluvial sediments consist of a sequence of clay, silt, sand, and gravel with minor calcareous, siliceous and ferruginous beds. Their thickness increases from 55 feet in the south to more than 230 feet in the northernmost bore. A very generalised sequence is described below.

A thin layer of coarse, brown, quartzo-feldspathic sand at the present surface is underlain by red-brown sandy silt and clay to a depth of 30 to 50 feet. The clays normally contain a small proportion of calcareous material as concretions, discrete layers, and encrustations. Above the water table gypsum and less commonly sodium carbonate and chloride may also be present.

Poorly sorted, silty sand and gravel occurring at a depth of about 40 or 50 feet are invariably at or below water level and contain iron-stained quartz, feldspar, chert, granite, agate, siltstone, quartzite, and various other rock types in addition to rounded pebbles and cobbles of basalt. The gravels are lenticular and their silt content varies widely. In old river channels the sands and gravels are far better developed ; for example in Bores 9 and 10 where they are respectively 40 and 56 feet thick and extend downwards to the bedrock surface.

Calcareous material deposited in the gravel forms kunkar, which may be white, brownish or pinkish, and is friable to very hard, with occasional vugs and veinlets of calcite. Manganese and ferruginous staining are common and there are traces of opaline silica. The maximum thickness penetrated is approximately 20 feet. A kunkar horizon was penetrated at about the 40-foot level in most bores and it appears to have a sheet-like form across the area (see Plate 2). It may have been deposited in the wide Yule River drainage valley at or near a former land surface when groundwater levels were close to that surface. In Bore 7 a very hard layer of silcrete occurs at the same level.

In the shallower bedrock areas, light brown and yellow clay, in places slightly calcareous, extends downwards to the bedrock surface beneath the sand or gravel. Where the bedrock is deeper a second sandy and gravelly horizon, similar to that described above, occurs between about 100 and 150 feet. Kunkar is not as well developed in this lower horizon and pebbles are less common.

Sandy clay and silt underlie the lower sandy horizon and grade from a brown to a light brown, khaki-yellow, often pinkish colour. In Bore 40, the northernmost bore drilled, a fine to medium-grained ferruginous sandstone containing anhydrite is developed. This may indicate that the northernmost part of the drilling area was at one time subject to marine inundation. The clay contains occasional rounded hematite granules which become more numerous with increasing depth. Hematite was not noted in any bore above the first sandy bed.

At a depth of about 180 feet, four bores in the northeastern part of the area intersected a hard, white, kaolinitic claystone overlying a hematitic and limonitic laterite, which in turn rests on the weathered bedrock surface. A thin band of hematite is developed within the laterite. In general, rounded hematite granules are common near the bedrock surface and in several other bores a thin, white, kaolinitic claystone was observed. It is possible that the claystone and laterite, which are devoid of spores and pollen, are remnants of a Tertiary lateritized surface.

Archaean

Archaean outcrops are shown on Plate 1. They are correlated with the Roebourne Group of the Pilbara System (Ryan, 1966). Bedrock types intersected were granite gneiss, leucocratic granite, hornblende-biotite granite, diorite, quartz-muscovite gneiss, quartzite, grey mica schist, purple mica schist, purple siltstone, light green siltstone, and banded chert. The maximum thickness penetrated, in Bore 20, was approximately 300 feet. The bedrock is kunkarised and is intruded by numerous quartz veins. In addition, the thick section of light green shale in Bore 20 contained thin siliceous and ferruginous interbeds with traces of quartz conglomerate and banded chert.

The weathering profile of the bedrock varies widely. The soft purple, greenish and grey shales, siltstones, and schists are quite deeply weathered to soft clays. The granites and quartzites, however, are normally not deeply weathered.

It is possible to divide the area into four roughly equal, east-west trending sections, each of which has a dominant bedrock type. From south to north in order they are :

1. granitic rocks,
2. friable, light grey-brown and pink, fine-grained, chloritic and pyritic quartzite,
3. soft, grey and greenish shale, and mica schist,
4. soft, purple, micaceous schist, and siltstone.

Leucocratic and hornblende-biotite granites are not restricted to the area of granitic rocks and are possibly intrusive.

HYDROLOGY

Flooding of the river

The Yule River is approximately 130 miles long and has a catchment area of about 4,200 square miles. In 1966 the river flowed for two months (4th-9th April and 28th April to 11th June) as a result of cyclonic rains. During this period Mundabullangana Station recorded 16·6 inches of rain.

At peak flood the maximum depth of water in the East Yule River at the North-West Coastal Highway crossing was 13 feet 7 inches, the width of the river at this point being 1,000 feet. If the average velocity of the river was 5 mph (a low estimate) the peak flow was about 45,000 cusecs.

Although records are incomplete it is known that from 1945-1966 the river flowed at least six times, an average of once every 3½ years. There is no record of a flow between 1952 and 1963 so possibly the maximum interval between flows is 11 years. The duration of flow on most occasions was only 4 or 5 days.

Periodic sampling of the flood water showed little variation in salinity of the East Yule from 100 to 215 parts per million of total dissolved solids. The salinity of the West Yule River, however, gradually rose from 100 to 2,500 ppm. A pool in the West Yule at the Highway crossing then increased in salinity to 7,220 ppm by October, 1966 whereas Lee Ling's Pool on the East Yule, apparently fed by river underflow, maintained a salinity of 150 to 200 ppm. It is probable that there is no appreciable thickness of river gravels in the West Yule, in which case underflow along this branch is negligible.

Groundwater occurrence

There are considered to be three aquifers in the Yule River area : the upper sand, lower sand, and bedrock aquifers.

The *upper sand aquifer*, the largest producer, corresponds to the lenticular, sandy to gravelly, often kunkarised layer which occurs at depths of about 40 or 50 feet over much of the area. The degree of sorting varies considerably, as does the percentage content of silt and clay. Silt and clay which usually overlie the aquifer are of low permeability and cause partial confinement. The degree of confinement varies with the permeability of the overlying beds, and with the position of the water level relative to those beds. Where the static water level is in the upper part of the confining layer the fine-grained material functions as a confining bed ; but when the water level declines into the more permeable material, the aquifer becomes progressively less confined. Near the river the aquifer is in direct hydraulic connection with the river gravel and is unconfined ; similarly, where the alluvial material overlying the aquifer is very sandy (e.g., Bore 51) the aquifer is also virtually unconfined.

The aquifer ranges in thickness from 8 feet up to 40 feet and averages about 20 feet thick. In Bores 9, 10B, and possibly 23 and 35B, old river gravels constitute the highest yielding aquifers in the area.

Water levels range from about 15 feet to 36 feet below ground level. In Gemco-hole 36A a perched water table was cut at approximately 7 feet.

The *lower sand aquifer* corresponds to the sandy and gravelly layer occurring at depths of between 100 and 150 feet. It is separated from the upper sand aquifer by about 50 or 60 feet of clay and is considered to be confined. Along the river it is apparently recharged directly from the river gravel.

The aquifer is only developed in the northern half of the area, roughly north of the abandoned Depuch railway line.

The lower sand is thinner and contains less coarse material than the upper sand. Its thickness ranges between 4 and 22 feet, the average being 13 feet.

Water levels appear to be similar to those in the upper sand. However in Bore 7A the water level was 4 feet higher and in Bore 40 the water level rose 1 foot 6 inches when the lower sand was cut. Both these bores are close to the river.

Bedrock aquifer. Generally bedrock was not penetrated to any great depth but pump test and salinity results suggest that it contains appreciable volumes of water. In rocks such as granite, gneiss, and quartzite the water is derived from joints, fractures, and quartz veins. In the softer, more clayey material such as shale, siltstone, and schist the water is probably derived solely from fractures in the quartz veins.

The bedrock aquifer appears to be in direct hydraulic connection with the river-bed gravels at least near Bore 7A. This suggests a thickness for the river gravels of perhaps 100 feet.

Groundwater quality

The area underlain by domestic quality water (i.e., water containing less than 1,000 ppm) is about 230 square miles. In the majority of bores water of greatest salinity occurred in the upper part of the upper sand and salinities decreased progressively with increasing depth. In fact, during several pump tests salinities improved to values less than those encountered during drilling. Thus in Bore 6 the total dissolved solids decreased from 1,360 ppm at 36 feet to 225 ppm at 200 feet, but the final salinity from a pump-test over the interval 37 to 78 feet was 195 ppm. The fresher water was apparently drawn in from the bedrock.

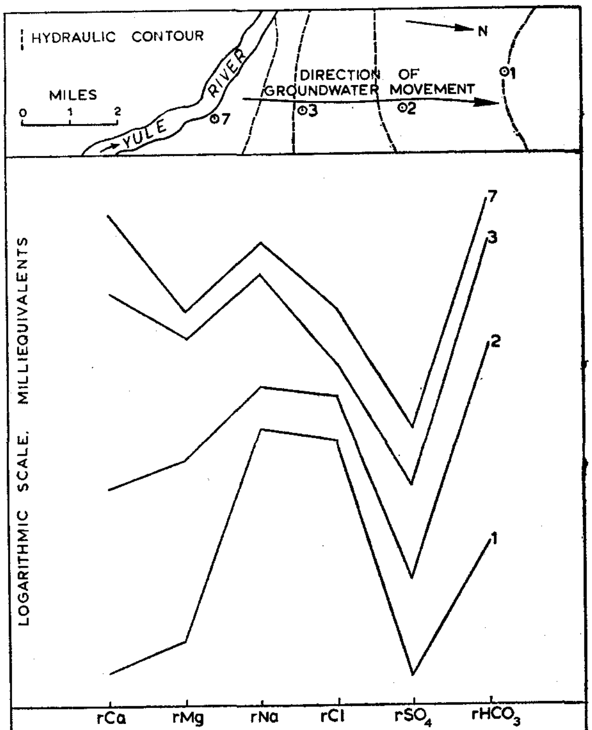
Isohalsines drawn on the best quality water in each bore are shown on Plate 3. They are parallel to the river and show a general increase in salinity away from it. This is indicative of recharge from the river and there is little evidence of localised recharge influencing the deeper salinities.

As a rule the upper, more saline water seldom extends more than 10 to 15 feet into the upper sand. This high salinity layer is a result of fluctuating water levels and of the high specific retention of the clay and silt which overlie the upper sand. Water levels are high during and after floods, and rise well within the clay and silt. When levels drop, water retained in the clay and silt becomes highly saline. Where evapotranspiration takes place, calcium carbonate and gypsum may be deposited. When water levels again rise, the rising fresher water is contaminated by the adsorbed salts and saline water. As a result the most pronounced extremes of salinity in the alluvium are encountered where the rises in water level are greatest and where the uncontaminated groundwater is freshest i.e., near the river. This is demonstrated by the high salinity variations in Bores 6, 12, and 40 which are alongside the river. Water in the bedrock is generally fresher than that in the alluvium.

Using salinity readings from station wells and bores which generally penetrate only a few feet into the upper sand, 1,000 ppm isohalsines for the top saline layer are shown on Plate 4. They are plotted for February, May, and June 1966 when water levels were progressively rising. It can be clearly seen that progressive contamination of the rising fresh water leads to a corresponding shrinkage in the apparent area of domestic-quality water. The isohalsines are parallel to the line of the river except in the northeast, where fresh water recharge from a well defined creek has elongated the isohalsines to the northeast, and in the central western section where there is an area of saline water intrusion. Neither of these effects is reflected by the deeper, fresher water.

Chemically the groundwater near the river is of a calcium bicarbonate type, but with increasing distance away from the river it changes to a sodium chloride type. Groundwater temperatures vary from 30·5 to 31·5°C. The water is alkaline (average pH 7·8) as a result of drainage from calcareous and basic Archaean rocks. Hardness, considered to be troublesome in excess of 200 to 300 ppm $CaCO_3$, averages 170 ppm, which is moderately high. The iron concentration as measured in the laboratory was rarely more than 0.1 ppm. However the precipitated iron is not measured and the actual iron content will be larger. Nevertheless the total iron concentration should not exceed the permissible 0·4 ppm. Fluoride concentrations were only determined towards the end of the programme and of seven measurements two were slightly in excess of the upper recommended limit of 1·4 ppm (maximum recorded 2 ppm).

The change from a calcium bicarbonate to a sodium chloride type water which is indicative of increasing distance travelled through the aquifer is shown on Figure 3, where concentrations of the mineral ions in water from Bores 7, 3, 2, and 1 are plotted as milliequivalents (denoted by r) on semi-logarithmic paper (Schoeller, 1959). These four bores were chosen because they lie in a line away from the river in the direction of groundwater movement. Noticeable chemical trends, apart from an increase in total salinity, are a progressive increase in rMg/rCa and rCl/rNa and a progressive decrease in $rHCO_3$ from Bore 7 through Bores 3 and 2 to Bore 1. These changes are indicative of recharge of the aquifer from the river (Schoeller, 1959).



FOR CLARITY THE GRAPHS HAVE BEEN VERTICALLY SEPARATED
NORMALLY THEY WOULD BE SUPERIMPOSED

BORE No.	SALINITY (TDS by evaporation)	DEPTH OF SAMPLE (FT)
7	190	55
3	220	53
2	820	42
1	2,520	49

FIGURE 3: GRAPH SHOWING VARIATION IN CHEMICAL QUALITY OF GROUNDWATER WITH DISTANCE TRAVELLED THROUGH AQUIFER IN YULE RIVER AREA

In Bores 7 and 7A which are alongside the river, a comparison of total salinity and chemical quality between river floodwater and groundwater in the upper sand, lower sand, and bed rock aquifers reveals no significant differences. This suggests that the river is direct hydraulic continuity with each of the three aquifers.

Pump test results and evaluation of formation constants

Where suitable aquifers were penetrated, 24-hour pump tests were conducted. Yields ranged from less than 1,000 to 12,700 gallons per hour. Results were analysed by the modified non-equilibrium method. In only one instance (Bores 10A/10B) was an observation bore available for use and results from this test were analysed by the Theis non-equilibrium method (Todd, 1963, and Walton, 1960).

Pump test results are summarised below:

Table 1

PUMP TEST RESULTS

Bore No.	Aquifer (feet from surface)	upper (u), lower (l) or bedrock (b)	Thickness (ft.)	Yield (gph.)	Specific Capacity (gph./ft. of drawdown)	Transmissibility (gpd./ft.)	Permeability (gpd./ft.²)
2	36–68	u	32	1,770	390	3,300	100
3	112–120; 125–126	l	9	5,600	1,120	13,700	1,520
4	56–80; 113–130	u + l	41	5,150	130	3,250	80
5	32–70	u	38	3,750	320	2,250	60
6	37–78	u	41	4,000	390	11,800	290
7	38–55	u	17	4,700	670	9,850	580
7A	(i) 110–130	l	20	2,350	30	....	....
	(ii) 250–270	b	20	4,200	230	4,300	210
8B	55–73	u	18	<1,000?	....	....	....
9	52–92	u	40	5,300	1,060	35,700	890
10B	35–75; 89–105	u	56	12,700	1,450	162,000	2,900
11	57–93	u	36	1,580	50	460	10
13	(i) 29–37	u	8	4,200	760	6,160	770
	(ii) 54–75	u	21	3,320	410	4,840	240
18B	137–154	l	17	2,510	70	420	20
20	(i) 38–56	u	18	2,650	190	1,420	80
	(ii) 160–168	u + l + b	?60 +	5,000	360	11,600	?
21	17–33	u	16	1,480	140	440	30
23	70–120	u	50	5,200	1,040	35,200	700
28	40–70	u	30	<1,480	<30	....	....
33	25–65	u	40	1,580	90	320	10
35B	40–80	u	40	8,500	1,060	40,000	1,000
40	165–185	l	20	4,800	220	9,600	480
44A	30–60	u	30	1,580	180	....	....
50	28–40; 97–110	u + l	25	3,000	170	930	70

The average permeability of the tested bores from the above table is 500 gpd/ft² but when assumed zero permeabilities for non-tested bores are included, the figure for mean permeability becomes 400 gpd/ft². There does not appear to be any significant permeability difference between the upper and lower sand aquifers (both about 400 gpd/ft²) but the one determination of bedrock permeability indicates a much lower value for this aquifer (210 gpd/ft²).

Changes in slope on the graphical plots of the pump test data reveal boundary conditions which are a result of the lenticular and discontinuous nature of the aquifers. Permeability values vary from almost zero up to about 3,000 gpd/ft². Unfortunately, analysis of results from a pumped bore is unreliable as well loss and other factors are not known. The permeabilities given in the above table are therefore to some extent inaccurate and any estimates of storage or recharge based on those values must be regarded as very approximate.

More accurate figures are available from the pump test on Bore 10B where Bore 10A, 90 feet distant, was used for observation. The results show that a boundary condition came into effect at about 5 hours and only data after that time can be analysed. The permeability derived from this analysis (Theis method) is shown below compared to values calculated by the modified non-equilibrium method.

Bore No.	Method	Permeability (gpd/ft²)
10A (observation)	Theis non-equilibrium	2,900
10A	Modified non-equilibrium	2,350
10B (pumping)	Modified non-equilibrium	3,650

The high ratio of the vertical permeability of the aquifer to that of the semi-confining clay is demonstrated by the instantaneous release of water from storage during the initial period of pump-testing. During this time only, the aquifer functions as a confined system. After the initial period of pumping it acts more as a water table aquifer.

The calculation of specific yield gives a value of 0·0112, i.e. intermediate between the values given by Todd (1963) for water table (S = 0·02 to 0·2) and confined aquifers (S = 0·00005 to 0·005). The highest yielding section of the aquifer in Bores 10A/10B is the lower section (89 to 105 feet). Unfortunately the slotted casing in the observation bore penetrated only the upper, more silty and clayey section (35 to 80 feet) and it is probable that the value of specific yield applies more to this section. Similar semi-confined silty sands and gravels in the Humboldt River Valley, Nevada (Cohen, 1964) have a specific yield of 0·04.

The permeability calculated from the pump-test on Bores 10A/10B is 2,900 gpd/ft² compared to the mean permeability of 400 gpd/ft² for the whole area. Therefore it is probable that the mean specific yield of aquifers on the flanks of the Yule River may be as low as 0·0015 (i.e., $\frac{400}{2,900}$ x 0·0112). However if account is taken of the as yet untested river bed sands, which may have a specific yield as high as 0·20 to 0·30, a mean specific yield of 0·005 is considered to be a conservative estimate.

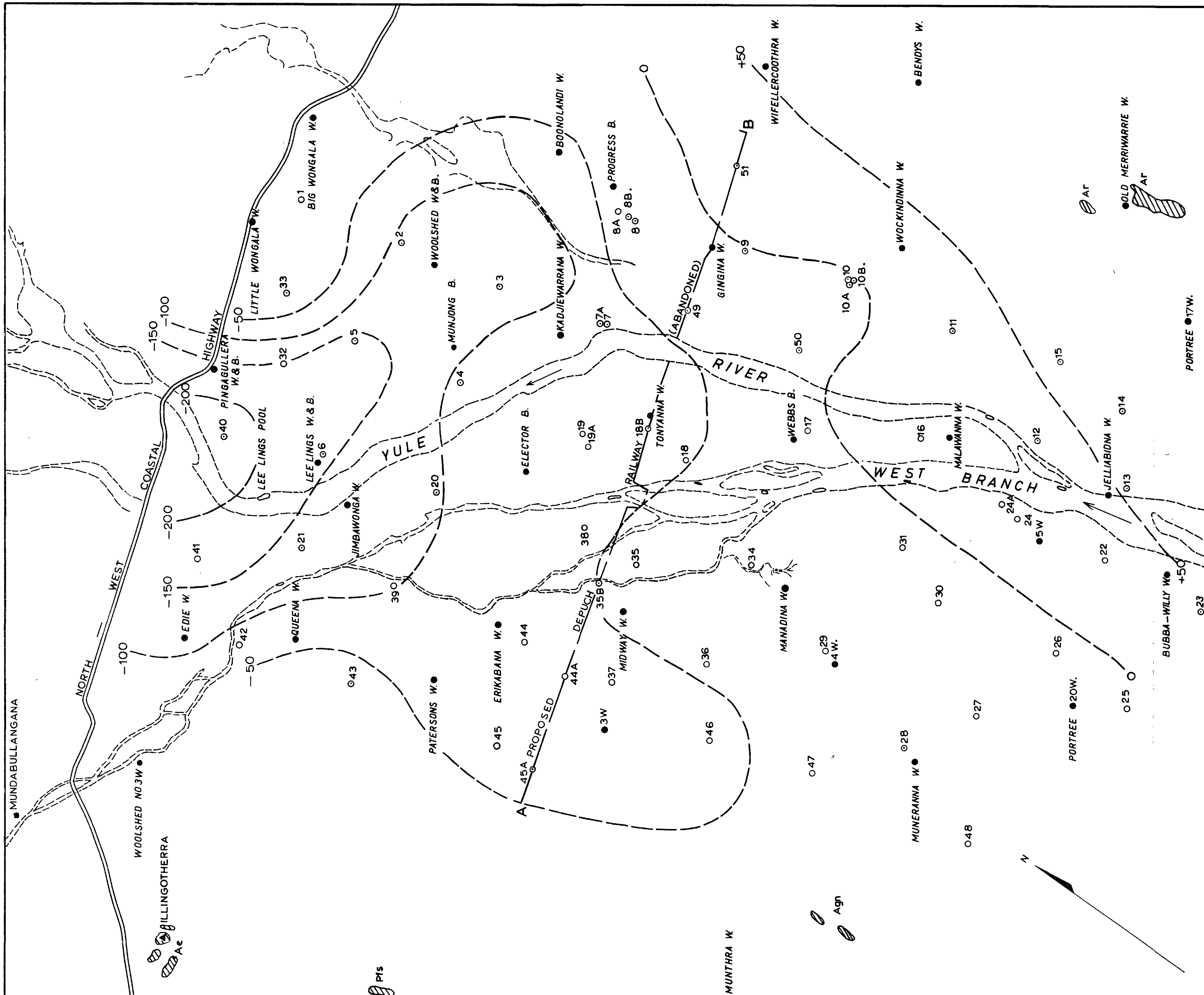
Groundwater movement

The direction of groundwater movement is perpendicular to the hydraulic contours shown on Plate 3 for October 1966. Groundwater flow is in a northerly direction along the river and in a northeasterly or northwesterly direction away from the river in the interfluves. Recharge from the West Yule appears to be ineffective about 5 miles below its diversion from the East Yule. The East Yule on the other hand is a major source of recharge at least as far north as the Coastal Highway.

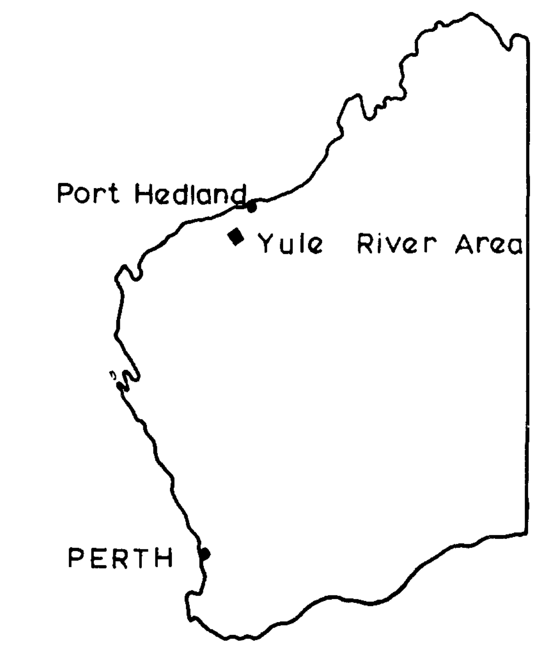
The hydraulic gradient is fairly constant to within about 6 miles of the Highway (i.e., approximately as far as Munjong Bore) and then flattens out. This suggests either that the permeability is increasing in that direction, which is contrary to the calculations made from pumping tests north and south of Munjong Bore, or that conditions had more or less stabilised after a long drought several years ago, and recent additions to the groundwater have caused a local build-up near the intake, not yet transmitted farther out.

A comparison is given below of longitudinal hydraulic gradients and rates of groundwater movement before and after the flooding of the river. It shows that after flooding the gradients and hence the rates of groundwater movement are appreciably higher.

	South of Munjong Bore (average permeability 470 gpd/ft²)	North of Munjong Bore (average permeability 140 gpd/ft²)
Hydraulic gradients Feb. 1966 (river not flowed for 3 years)	6.1 ft/mile	3.3 ft/mile
Rate of groundwater movement	0.088 ft/day	0.014 ft/day
Hydraulic gradients Oct. 1966 (river flowed April-June)	6.4 ft/mile	4.3 ft/mile
Rate of groundwater movement	0.090 ft/day	0.018 ft/day



LOCALITY MAP



REFERENCE

PROTEROZOIC	Pfs	:Sandstone and tuff
ARCHAEAN	Agn	:Granite gneiss
	Ae	:Porphyry, breccia, and siliceous rocks
	Ar	:Quartz-greywacke, siltstone, and calcareous shale

SYMBOLS

- ⊙ PERCUSSION HOLE (LEFT FOR OBSERVATION)
- ○ GEMCO AUGER HOLE (ABANDONED)
- ● STATION WELL OR BORE
- +50 BEDROCK CONTOURS (RELATIVE TO LOW WATER MARK, FREMANTLE)

SCALE OF MILES

1 0 1 2 3

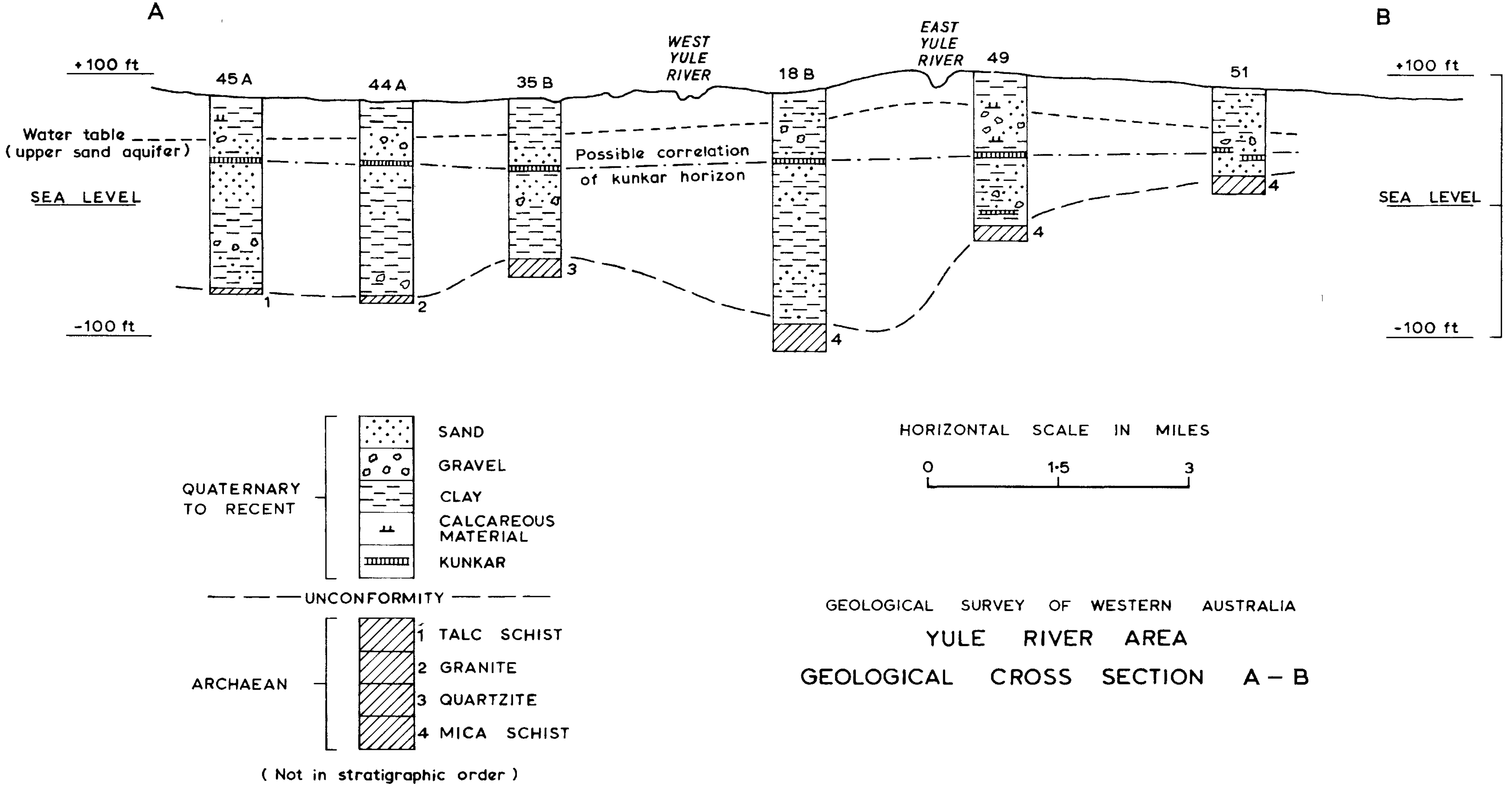
GEOLOGICAL SURVEY OF WESTERN AUSTRALIA

YULE RIVER AREA

PLAN SHOWING BEDROCK OUTCROPS, BEDROCK CONTOURS, AND LOCATION OF BORES AND WELLS

To accompany report by P.Whincup

9678



GEOLOGICAL SURVEY OF WESTERN AUSTRALIA

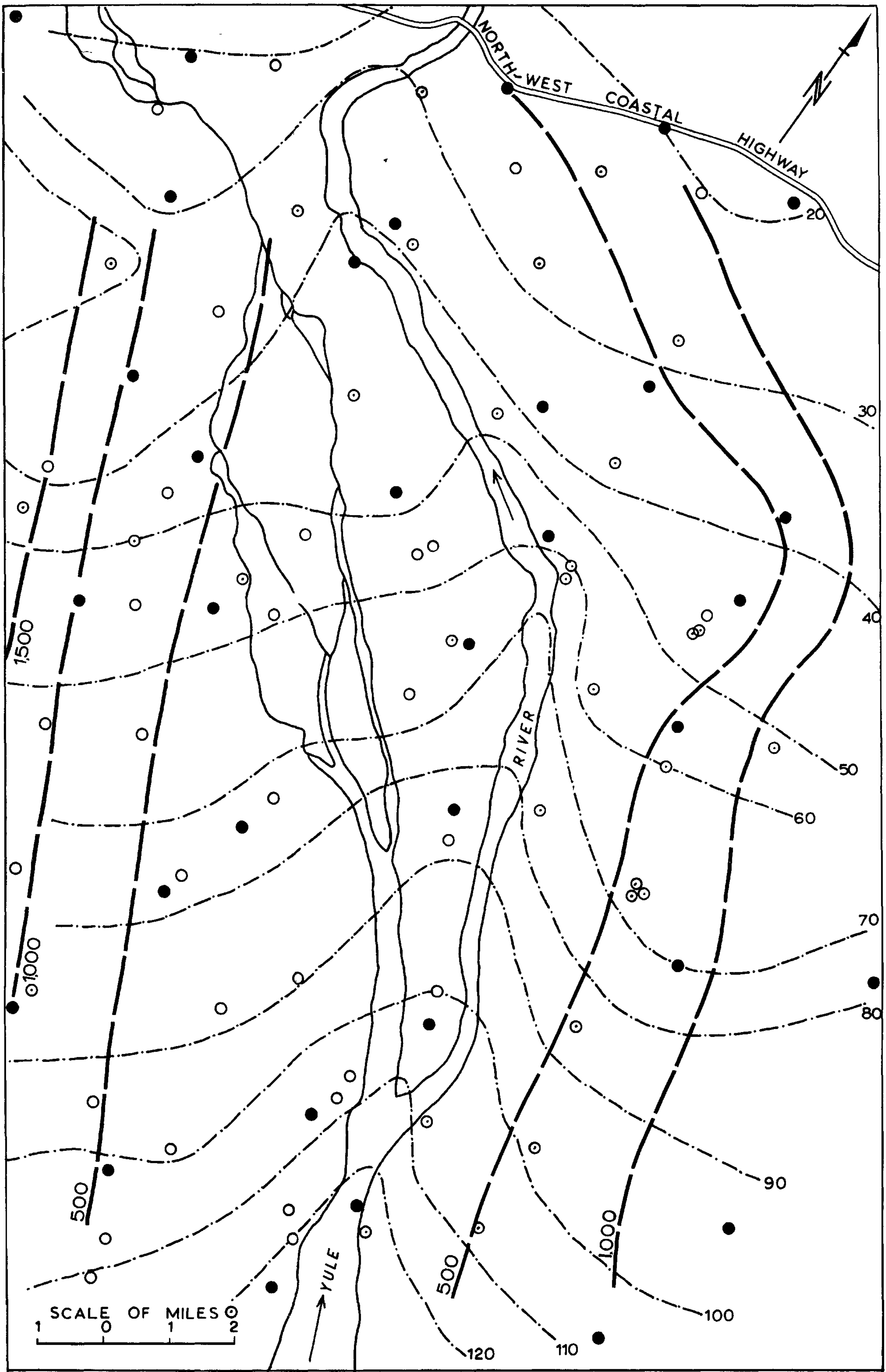
YULE RIVER AREA

GEOLOGICAL CROSS SECTION A – B

To accompany report by P. Whincup. 1966

9679

PLATE 3



500 ISOHALSINES IN PARTS PER MILLION OF TOTAL DISSOLVED SALTS (USING VALUES OF LOWEST SALINITY IN EACH BORE)

80 HYDRAULIC CONTOURS (IN FEET ABOVE LOW WATER MARK FREMANTLE) ON 4th. OCTOBER, 1966

⊙ OBSERVATION BORE

○ ABANDONED GEMCO HOLE

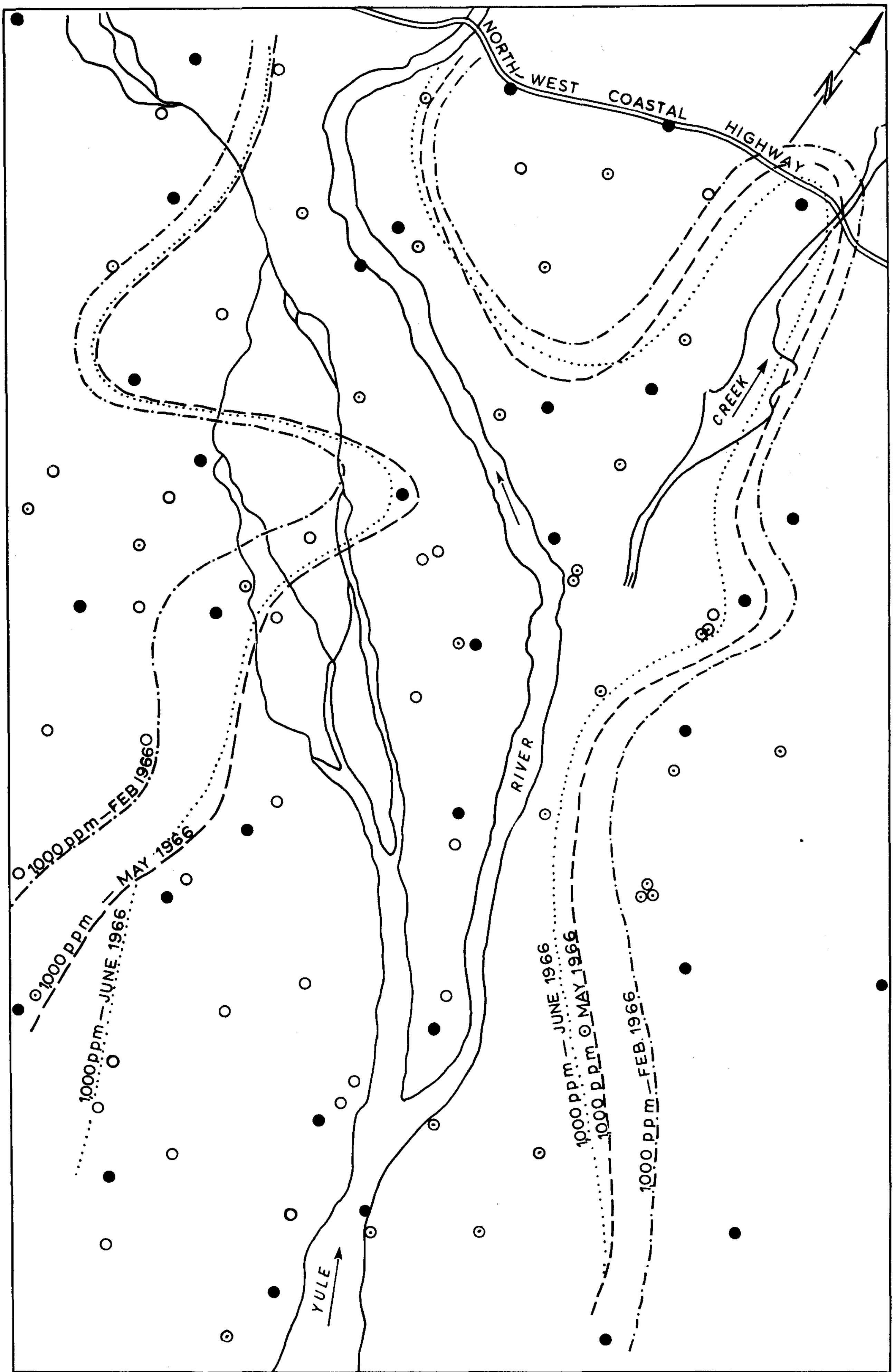
● STATION WELL OR BORE

GEOLOGICAL SURVEY OF WESTERN AUSTRALIA

YULE RIVER AREA
ISOHALSINES AND HYDRAULIC CONTOURS

To accompany report by P. Whincup

9680



⊙ OBSERVATION BORE
○ ABANDONED GEMCO HOLE
● STATION WELL OR BORE

SCALE OF MILES
2 1 0 1 2

SALINITY MEASUREMENTS WERE MADE ON SAMPLES FROM STATION WELLS AND BORES WHICH ONLY PENETRATE THE UPPER MORE SALINE PART OF THE AQUIFER

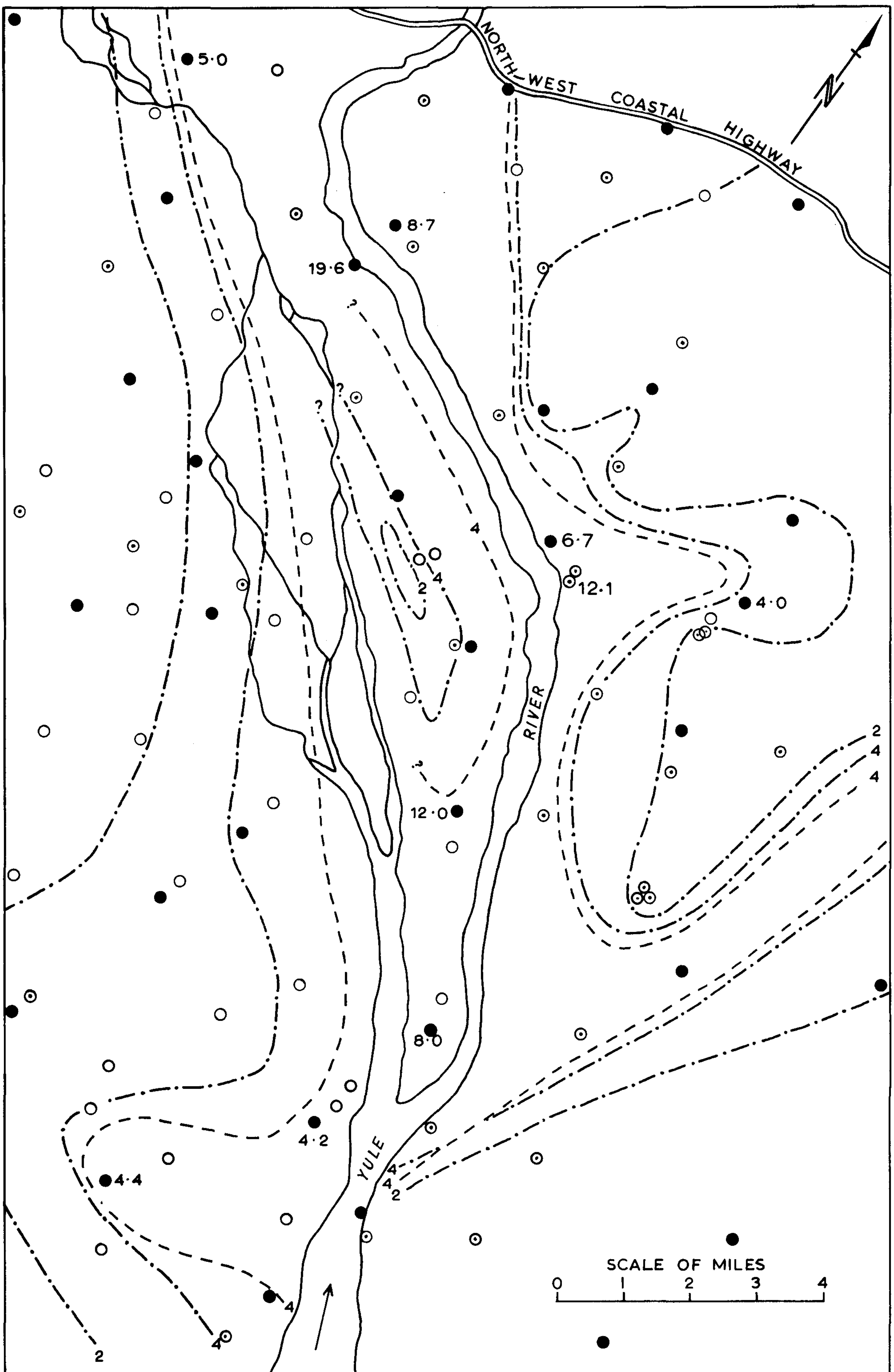
GEOLOGICAL SURVEY OF WESTERN AUSTRALIA

YULE RIVER AREA
ISOHALSINES ON THE OVERLYING SALINE GROUNDWATER
FEBRUARY TO JUNE 1966

To accompany report by P. Whincup

9681

PLATE 5



4 —·—· CONTOUR SHOWING RISE IN FEET OF WATER LEVELS FROM THE 26th. FEB. TO THE 22nd MAY, 1966

2 — — — CONTOUR SHOWING RISE IN FEET OF WATER LEVELS FROM THE 26th. FEB. TO THE 17th AUG, 1966

⊙ OBSERVATION BORE
○ ABANDONED GEMCO HOLE
● STATION WELL OR BORE

WHERE RISES IN LEVEL ON 22nd MAY WERE MORE THAN 4 FEET THE FIGURE IS SHOWN ON THE PLAN

GEOLOGICAL SURVEY OF WESTERN AUSTRALIA

YULE RIVER AREA
CONTOURS SHOWING RISES IN WATER LEVELS AFTER FLOODING

To accompany report by P. Whincup

9682

Recharge

Hydraulic and salinity patterns show that recharge occurs almost entirely from the river. Minor localised recharge, as indicated by slight variations in hydraulic contours and upper, saline isohalsines, is negligible.

Rises in water level, calculated by subtracting water level readings in February from water levels measured at intervals after the river had flooded, are summarised on Plate 5. Contours on the 4-foot rise in water level from February to May 1966 are shown as are the contours on the 2 and 4-foot rise from February to August 1966. The latter contours demonstrate that in August, three months after the river had flooded, water levels were still rising in the interfluves. The rises in water level are greater near the river, the maximum recorded being 20 feet 6 inches at Jimbawonga Well.

In the more permeable zones the water level does not rise as much as in the less permeable zones. Thus the large area of small water level rises near Bores 9 and 10B is an indication of high permeabilities in that area.

Rises in water level have been used to determine the volume of water entering the upper sand aquifer during the river flooding, as shown in the table below.

Average rise in water level (feet)	Area (sq. miles)	Increase in volume of saturated aquifer
1.5	54	81 X 5280^2
3	66	198 ,,
5	60	300 ,,
7	30	210 ,,
8	19	152 ,,
		Total 941 X 5280^2

Increase in volume of saturated aquifer = 941 x 5280^2 cu ft.

Volume available for withdrawal = Specific yield x Increase in volume of saturated aquifer
= 0·005 x 941 x 5280^2 x 6·25 gallons
= 800 million gallons (approx.)

Assuming that the river floods once every 3·5 years the amount of water per day available for withdrawal, if it can be fully recovered from the aquifer,

$$= \frac{800 \times 10^6}{3 \cdot 5 \times 365} \text{ gallons per day}$$

= 640,000 gallons per day

This calculation assumes no decline in level resulting from outflow, although in theory all recharge would be so lost after 3.5 years. However, if the production field is restricted in area, over-abstraction will draw water in from all sides and there will be no outflow lost from this dewatered area. The 640,000 gallons per day would then be the maximum available immediately after a flood occurs.

The volume of water entering the lower, confined aquifers would be considerably less than that entering the upper sand aquifer.

Subsurface flow

Estimates have been made of subsurface flow across the line of the abandoned Depuch railway which is roughly perpendicular to the direction of groundwater movement. The figures for permeability and aquifer thickness are the average for Bores 51, 49, 18B, 35B, and 44A.

Length of cross section between 1,000 ppm isohalsines = $10\frac{1}{2}$ miles

Average permeability = 360 gpd/ft^2

Gradient (figure for Feb. and Oct. 1966 is similar) = 5 ft/mile

Average aquifer thickness (upper and lower sand combined) = 38 feet

Subsurface flow = Permeability x Gradient x Thickness x Width

$$= 360 \times \frac{5}{5280} \times 38 \times 10 \cdot 5 \times 5280 \text{ gallons/day}$$

= 720,000 gallons per day.

Total storage in upper and lower sand aquifers

The area underlain by the upper sand aquifer is 230 square miles and the average aquifer thickness (from 28 bores) is 27 feet. The corresponding figures for the lower sand aquifer are 80 square miles and 13 feet (from 12 bores).

Total volume of aquifers = [(230 x 27) + (80 x 13)] [5280^2] cu ft.

Total Volume of water stored
= Total volume x Specific yield
= [(230 x 27) + (80 x 13)] [5280^2 x 6·25 x 0·005] gallons
= 6,300 million gallons

Bore spacing

In order to make estimates of a suitable production bore spacing, drawdowns after $3\frac{1}{2}$ years continuous pumping (the average recharge interval) have been calculated for five bores i.e. Nos. 3, 7, 9B, 10B, and 50. The drawdowns were derived from the modified non-equilibrium method and it was assumed that drawdowns through this time interval would bear a constant relationship to those experienced at the end of the 24-hour pump tests. However, if further boundary conditions were to come into effect, as is possible, drawdowns could be considerably greater.

In addition to the drawdowns in the pumped bores, the drawdown interferences at distances of 500 and 2,000 feet have been calculated with additional calculations at 4,000 and 8,000 feet for Bores 7 and 50. These figures were derived from the following equations:

$$r^2 = \frac{Tut}{2242S} \text{ and } d = \frac{114 \cdot 6\, QW(u)}{T} \text{ (see Todd, 1963)}$$

where r = distance from pumped bore (feet)
T = transmissibility (gallons per day per foot)
t = time (minutes)
S = specific yield
d = drawdown (feet)
Q = yield (gallons per minute)
u and W(u) = well constants.

Results are summarised below but are only approximate as transmissibilities vary widely, even over a distance of 500 feet. The specific yields have been taken as 0·01 in Bores 9B and 10B and 0·001 in the other bores.

Bore No.	Assumed S	Q	Available drawdown (feet)	Calculated drawdown after $3\frac{1}{2}$ years				
				In pumped bore (feet)	At a distance of			
					500 feet	2,000 feet	4,000 feet	8,000 feet
3	0.001	90	90	14	$9\frac{1}{2}$	$5\frac{1}{2}$	....	....
7	0.001	80	?20	21	$9\frac{1}{2}$	7	5	4
9B	0.01	170	62	20	5	$3\frac{1}{2}$	....	....
10B	0.01	200	74	9	$1\frac{1}{2}$	1	....	....
50	0.001	50	?16	85	43	27	20	$11\frac{1}{2}$

It can be seen that along the high transmissibility old river bed intersected in Bores 9B and 10B, drawdowns and drawdown interferences are very small. Bore spacing along the old river bed could be of the order of 500 feet and a similar spacing could be considered along the present river course, if development is undertaken there.

However Bore 7 is probably more typical of interfluvial production bores and a spacing of 2,000 feet for such bores would be the minimim figure. Thus considering Bore 9B:

Drawdown in Bore 9B after $3\frac{1}{2}$ years	= 20 feet
Drawdown interference from four production bores similar to Bore 7, each 2,000 feet distant from bore 9B	= 4 x 7 feet = 28 feet
Drawdown from four production bores, each 4,000 feet distant	= 4 x 5 feet = 20 feet
Total Drawdown	= 68 feet
Available Drawdown	= 62 feet

Low transmissibility aquifers, such as those cut in Bore 50 should not be developed, as even at distances of 8,000 feet, drawdowns are considerable.

The most economical means of developing the field appears to be by siting production bores along the buried river channel between Bores 9 and 10B and along the present river course.

CONCLUSIONS AND RECOMMENDATIONS

Development of the Yule River area is recommended. Based on aquifer constants which must be regarded as very approximate it is calculated that a very maximum of 1.3 million gallons per day of domestic quality water might be available immediately after a river flood, and this could fall to 720,000 gallons per day without drawing on storage. In addition, some of the 6,300 million gallons of stored water could be mined if necessary, plus some extra from the underlying bedrock. Estimated township needs for 1978 can therefore be met, if the Turner River reserves are included.

The most favourable area for initial development is that within which Bores 9B, 10B, and 49 are situated and less particularly the northerly continuation of that area through Bores 7 and 7A to 3. Bores 9B and 10B intersected gravel laid down in an old course of the river and each is capable of producing between 10,000 and 15,000 gallons per hour.

Development should preferably be concentrated near the river to draw on river underflow and also to avoid pulling in saline water from the interfluves. If the required supply of 0·8 million gallons per day is taken from a small area, ground water will be mined, considering that the volume available from the whole area is 1·3 million gallons per day. Therefore production bores should be separated as far as is economic. A separation of 2,000 feet is recommended in the interfluves but in areas of high transmissibility such as along the present river course and the old river channel between Bores 9 and 10B, a minimum separation of 500 feet is possible. Mining of water on a small scale however is not dangerous as it will permit greater recharge of the aquifers during river floods than is possible under natural conditions.

It possible the river bed should be drilled to test the thickness of the river sands and gravels, as sumps in the river bed could be capable of producing large supplies. It appears that the river sands are in direct contact with the bedrock aquifer indicating a thickness of perhaps 100 feet of coarse fluviatile material.

Controlled pump-testing of up to 48 hours duration should be carried out with observation bores, to obtain more information on specific yields and thus modify the calculated figures for storage and recharge.

Monthly readings of water levels in observation bores should be taken to delineate the pattern of natural water level movement and the degree of disturbance by pumping when major abstraction commences. Salinity readings should also be taken, perhaps at three-monthly intervals.

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EXPLORATORY DRILLING FOR GROUNDWATER AT JURIEN BAY

by R. Milbourne

ABSTRACT

An adequate supply of low salinity groundwater can be obtained from the Pleistocene Coastal Limestone 3 miles east of Jurien Bay. Recharge is both local and from the east, where laterite capped breakaways flank the intake area. Groundwater salinity increases towards the coast.

INTRODUCTION

Jurien Bay is a small township located on the coast about 175 miles by road north of Perth (Plate 6). It is principally a crayfish processing and fishing centre and is increasing in popularity as a seasonal holiday resort.

The Mines Department was requested by the Public Works Department to locate suitable groundwater for a town water supply, and subsequently undertook an exploratory drilling programme in 1962. One deep bore was drilled to 682 feet, and seven shallow bores were drilled to depths between 17 feet and 35 feet. This drilling (Berliat and Morgan, 1962) showed that a limited quantity of water (1,200 to 1,400 ppm TDS) could be obtained from below fixed sand dunes, ½ mile from the coast, at depths between 25 feet and 35 feet.

The population of the town at Jurien Bay is expanding and the Public Works Department again requested the assistance of the Mines Department in locating further supplies of suitable groundwater. Subsequently another drilling programme was undertaken between December 1965 and April 1966, and seven exploration bores were drilled to depths between 120 feet and 150 feet. This drilling was located 1½ to 3½ miles east of Jurien Bay and extended from northeast to southwest for about 2½ miles, forming a triangle with the apex pointing northward, flanked to the east by the subsurface Beagle Fault, and to the west by the coast.

There are no rainfall records available for the drilling area, but the short term annual rainfall at Cockleshell Gully (about 10 miles north) has been recorded as 23·76 inches per annum and is assumed to be fairly representative of the drilling area.

PHYSIOGRAPHY

The topography is dominated by Quaternary Coastal Limestone which rises to form a minor escarpment (the 'greater ridge'), 2 miles east of Jurien Bay and roughly at R.L. 100 feet (Plate 6). The following four natural divisions occur in the topography eastwards from the Jurien Bay coast.

1. A graduation from the strandline to mobile and fixed sand dunes about ¼ to ½ mile inland.

2. Sandy coastal lowland which extends for approximately 1 mile up to and including the low sandy 'lesser ridge'. This ridge trends northeast and is almost parallel to the coast.

3. A shallow trough separates the 'lesser ridge' from the 'greater ridge' or limestone scarp, and this limestone continues eastward for about 5 miles as rounded hills with 'pinnacle' outcrops. This merges into the following division.

4. Sands derived from the Jurassic—Cretaceous Cadda Formation forming laterite-capped breakaways about 10 miles from the coast.

EXPLORATORY DRILLING

The availability of groundwater in division 1 has been established by Berliat and Morgan, who concluded that a limited quantity of suitable groundwater could be obtained from below the fixed sand dunes ½ mile from the coast. Chemical analyses from this drilling are included in Table 2.

Exploratory drilling during 1966 has shown that larger quantities of low salinity groundwater can be obtained in the Coastal Limestone between the 'greater ridge' and the Beagle Fault. A summary of the hydrology obtained from drilling is included in Table 1, and the respective chemical analyses are given in Table 2.

Table 1
SUMMARY OF RESULTS—JURIEN BAY WATER BORES

GSWA Bores (Plate 6)	1	2	3	4	5	6	7	8	9	10	11	12
Total depth	628′	35′	24′	30′	33′	127′	120′	130′	150′	150′	150′	150′
Reduced levels	10′ app.	10′ app.	4′ app.	10′ app.	10′ app.	6.15′	13.60′	10.04′	24.08′	105.25′	64.27′	87.33′
Aquifer (below N.S.)	10–87′ 500–595′	11–35′	13–24′	14–30′	12–33′	27–37′	33–44′	27–37′	37–47′	98–100′	78–88′	100–110′
Standing water level	6′	9′	?	9.75′	12′	5′ 5″	12′ 7″	10′ 10″	23′ 0″	96′ 0″	64′ 9″	86′ 8″
Pumping rate 1 (gph)	not tested	530	not tested	not tested	2,000	1,800	2,196	700	2,200	bailed dry 2000 gpd	2,200	2,600
Drawdown	....	5′	....	....	12′	1″	1″	13′ 0″	8″	34′ 0″	2″	3″
Salinity (ppm TDS)	too high	860 (NaCl)	too high	too high	1,070	1,430	920	1,050	670	730	690	640
Pumping rate 2 (gph)	....	....	....	....	1,200	2,000*	10,200†	....	3,500	....	10,800†	10,600†
Drawdown	....	....	....	....	8′	3″	12″	....	1′ 3″	....	2′ 4″	10″
Salinity (ppm TDS)	....	....	....	....	1,070	1,480	940	....	700	....	700	640
Pumping rate 3 (gph)	....	....	....	....	....	7,000	16,200	....	6,000†	....	....	18,000
Drawdown	....	....	....	....	....	11″	2′ 3″	....	10′ 1″	....	....	2′ 0″
Salinity (ppm TDS)	....	....	....	....	....	1,790	950	....	800	....	....	640

* 8 hour pump test. † 48 hour pump test.

Table 2
STANDARD CHEMICAL ANALYSES—JURIEN BAY WATER BORES

Bore No.	1*	2A*	4*	5*	6	7	7	8	9	9	10	11	11	12	12
Nature of sample	s	s	s	s	f	i	e	f	i	e	f	i	e	i	e
Specific conductivity (micromhos 20°C)	....	....	....	....	2110	1310	1340	1500	970	1000	1040	1020	1000	930	920
pH	6.7	7.7	7.3	7.6	7.4	7.2	7.4	7.5	7.4	7.4	7.9	7.3	7.6	7.4	7.2
Mineral matter—															
Total dissolved solids ppm by—															
evaporation	49,300	1166	2670	1268	1290	850	760	910	600	620	620	640	630	590	580
conductivity	....	1283	2937	1395	1480	920	940	1050	680	700	730	710	700	650	640
NaCl	45,700	....	....	....	905	507	493	564	317	337	387	347	351	303	301
Total hardness	8,180	455	670	487	412	321	323	380	283	293	261	282	283	288	283
Total alkalinity	....	....	....	....	238	240	238	281	228	238	181	222	222	228	228
Ca	1280	57	92	50	99	94	95	93	79	81	77	88	87	92	90
Mg	1210	76	107	88	40	21	21	36	21	22	17	15	16	14	14
Na	15,400	200	677	226	305	177	161	189	112	119	126	119	122	99	101
K	570	6	24	6	12	9	8	6	2	3	5	4	4	3	4
Fe	....	....	....	....	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
HCO_3	64	427	462	438	290	293	290	342	278	290	221	271	271	278	278
SO_4	3160	45	135	52	74	41	21	35	25	24	27	24	28	37	21
Cl	27,700	353	1170	404	549	307	299	342	192	204	235	210	213	183	183
NO_3	2	2	3	4	2	2	2	1	5	5	2	2	1	2	0.1
SiO_2	....	....	....	....	13	12	11	12	8	9	7	10	11	9	9

* After Berliat and Morgan (1962).
s Static sample.
i Sample taken at beginning of pump test (48 hour).
e Sample taken at end of pump test (48 hour).
f Sample taken at end of pump test (8 hour).

Bore 6 encountered water at 12 feet (3,880 ppm TDS) in quartz sand containing seaweed and abundant coarse shelly grit, typical of lagoonal sediments deposited as a result of an actively advancing coast. Coastal Limestone was found at 27 feet and the groundwater salinity within the limestone was 1,430 ppm TDS. This salinity rose to 1,790 ppm as the pumping rate increased from 1,800 gph to 7,000 gph but dropped again to 1,480 ppm when the pumping rate was reduced to 2,000 gph, suggesting a degree of salt encroachment proportional to the pumping rate. A one inch drawdown was recorded during the 1,800 to 2,000 gph pump tests and an 11 inch drawdown was recorded during the 7,000 gph pump test. The recovery time was too rapid to be recorded.

Bore 7 was drilled in limestone about 1 mile southeast of Bore 6 and pump tested from 2,200 to 16,200 gph without appreciable variation in salinity (920 to 950 ppm TDS). The drawdown varied from 1 inch to 2 feet 3 inches, and the maximum recovery rate of 2 minutes 25 seconds was recorded. This suggests that a large quantity of groundwater of less than 1,000 ppm TDS can be obtained from the Coastal Limestone at this site.

Bore 8 is located about halfway between Bores 6 and 7 and the drilling has shown that 12 feet of fine-grained eolian beach sand containing numerous gastropod shells overlies the Coastal Limestone. This bore was pump tested at a maximum of 700 gph for a drawdown of 13 feet, the salinity being 1,050 ppm. A discontinuity apparently exists in the aquifer between this bore and the two previous bores.

Bore 9, 2½ miles to the northeast, was pump tested from 2,200 to 6,000 gph, and produced low salinity (670-700 ppm TDS) groundwater from the Coastal Limestone. Drawdowns varied from 8 inches to 10 feet 1 inch with a maximum recovery time of 2 minutes. The bore was in danger of forking at 7,000 gph.

Bore 10 proved to be the least productive of this programme, yielding an estimated 2,000 gpd supply of 730 ppm TDS groundwater. The sub surface Beagle Fault passes close to this bore and may have some influence on its hydrology.

Bore 11, situated about halfway between Bores 9 and 10, was pump tested at 2,200 and 10,800 gph without any appreciable increase in salinity (690 to 700 ppm TDS), with drawdowns of 2 inches to 2 feet 4 inches respectively, and a maximum recovery time of 2 minutes. This bore gave good results for this programme and is very suitable for the town water supply.

Bore 12, located 2 miles northeast of Bore 11 was pump tested from 2,600 to 18,000 gph, and, within this range, the groundwater salinity remained constant at 640 ppm. The drawdown increased from 3 inches to 24 inches, and the maximum recovery time was 2 minutes 55 seconds. This bore is also suitable for the town water supply.

PALYNOLOGY

Samples of silt and silty sand were palynologically examined from Bores 6, 7, 8, 10, and 11 and the results are summarised below:

Bore	*Depth*	*Age*
6	127 feet	Middle Triassic
7	99 feet	Middle Triassic
8	130 feet	Middle Triassic
10	150 feet	barren
11	96–116 feet	probable Quaternary

GEOLOGY

Sections A–A$_1$ and B–B$_1$ (Plate 6) are constructed from borehole data and infer the subsurface geology and structure.

The section through A–A$_1$ shows that the probable Quaternary sediments between the Middle Triassic siltstone and Pleistocene calcarenite thickens towards the north. A shallow trough exists between Bores 11 and 12, forming a probable recharge axis from the east-northeast.

The section through B–B$_1$ shows that Middle Triassic clayey siltstone is separated from the overlying sediments by an unconformity. Between this unconformity and the base of the Pleistocene Coastal Limestone is a wedge of sediments thinning to the west and believed to have been deposited during the Quaternary.

Recent eolian calcarenite has been deposited on the wave cut limestone and in the minor depressions and valleys immediately to the east.

HYDROLOGY

The water table of the drilling area is fairly constant at about sea level, with the exception of Bore 10 which, in addition to a low groundwater yield, had a water level of 9 feet above sea level.

The section along B–B$_1$ shows the aquifer extending through Bores 6, 7, 8, and 11, with the standing water levels close to sea level. An apparent domelike subsurface feature is probably responsible for the discontinuance of the aquifer and the higher water level at Bore 10.

Groundwater is obtained from Bore 6 at a depth of 12 feet, but the salinity (3,880 ppm TDS) is higher than that of the groundwater obtained from the limestone at 30 feet, indicating that partly diluted connate seawater still remains in the overlying sand. The top of the aquifer probably coincides with the top of the Coastal Limestone, resulting in the upward seepage of pressure water into the overlying sand, and the continual reduction in salinity by flushing.

The section along A–A$_1$ shows that the aquifer forms a shallow trough from Bore 9 to Bores 12 and 11, suggesting a direction of recharge from the northeast and at right angles to the salinity contours. The aquifer is at its shallowest at Bore 9, where the capacity is limited (10 feet drawdown at 6,000 gph) by another apparent domelike subsurface feature.

A considerable amount of rainfall is absorbed into the Coastal Limestone, forming an additional source of recharge.

CONCLUSIONS AND RECOMMENDATIONS

Within the area of the current exploration programme the Coastal Limestone appears capable of yielding large quantities of low salinity groundwater from the hills to the east of the Jurien Bay coastal lowland.

It is recommended that the siting of production holes for the Jurien Bay township water supply be restricted to the triangle formed by the Bores 9, 11, and 12.

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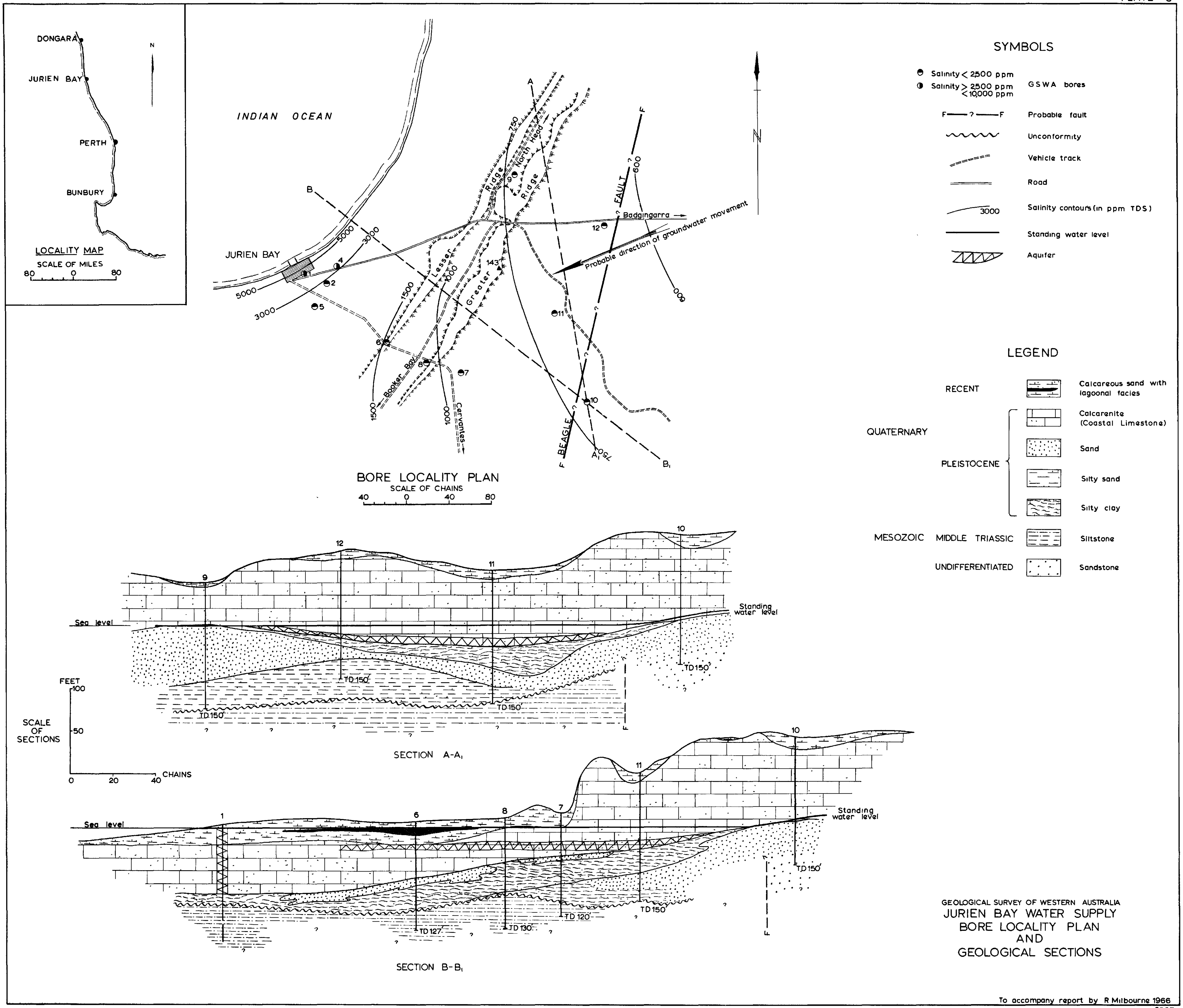


GEOLOGICAL SURVEY OF WESTERN AUSTRALIA

JURIEN BAY WATER SUPPLY
BORE LOCALITY PLAN
AND
GEOLOGICAL SECTIONS

To accompany report by R Milbourne 1966

9397

PORT HEDLAND TOWN WATER SUPPLY, TURNER RIVER EXPLORATORY DRILLING

by R. A. Farbridge
(with additional data by T. T. Bestow and J. R. Passmore)

ABSTRACT

During a hydrological investigation of the lower Turner River, 22 bores were drilled, from which water and strata samples were tested. Sixteen bores were pump-tested at rates of 200 to 6,000 gph. Recharge occurs from the river, but saline water exists close to the production area.

Further development is not recommended. If recharge occurs within every 3 years, present production represents a safe maximum, but if the river flows less frequently, then the present rate of pumping exceeds the normal inflow into the bore field.

INTRODUCTION

The Turner River area was investigated on behalf of the Public Works Department to find out if the existing production of 200,000 gallons per day could be increased to the future requirement of 1¼ million gallons per day.

Location

The Turner River flows northwards and crosses the North-West Coastal Highway about 19 miles west of Port Hedland (Fig. 4). The area investigated was mainly south of the highway, and extended 9½ miles upstream.

Previous work

Sands in the east branch of the river near Boodarie homestead were tested in 1925 and 1926. Hobson (1948a, b) summarised these results and also recommended drilling of the present P.W.D. production area and Pippingarra Creek 16 miles to the east.

Allen (1964) suggested the present exploratory drilling to determine the extent of the low salinity water body, the thickness of alluvium, and the amount of water available.

Present investigation

Between March and December 1965, 22 exploratory bores were drilled by a percussion cable tool rig, over an area of 54 square miles.

CLIMATE AND VEGETATION

The average annual rainfall is 12·56 inches, but yearly falls between 40·13 inches and 1·25 inches have been recorded. This rainfall is cyclonic and falls mainly during the period January to March. It is irregular and of scattered distribution. Summers are hot and dry, with a high potential evaporation of 98 inches (calculated value for Port Hedland airport).

The area is one of spinifex sandplain with clay pans; eucalyptus grow along drainage lines and mangroves fringe the coast.

TOPOGRAPHY AND DRAINAGE

The coastal plain has a gentle slope down to the north of about 7½ feet per mile. Low hills of basement rock crop out about 13 miles upstream of the coastal highway. The northerly flowing rivers have irregular, often braided channels and in some places are confined by banks. Sandplain or clay pans cover the interfluves. Northerly sand ridges possibly represent abandoned river channels or river banks.

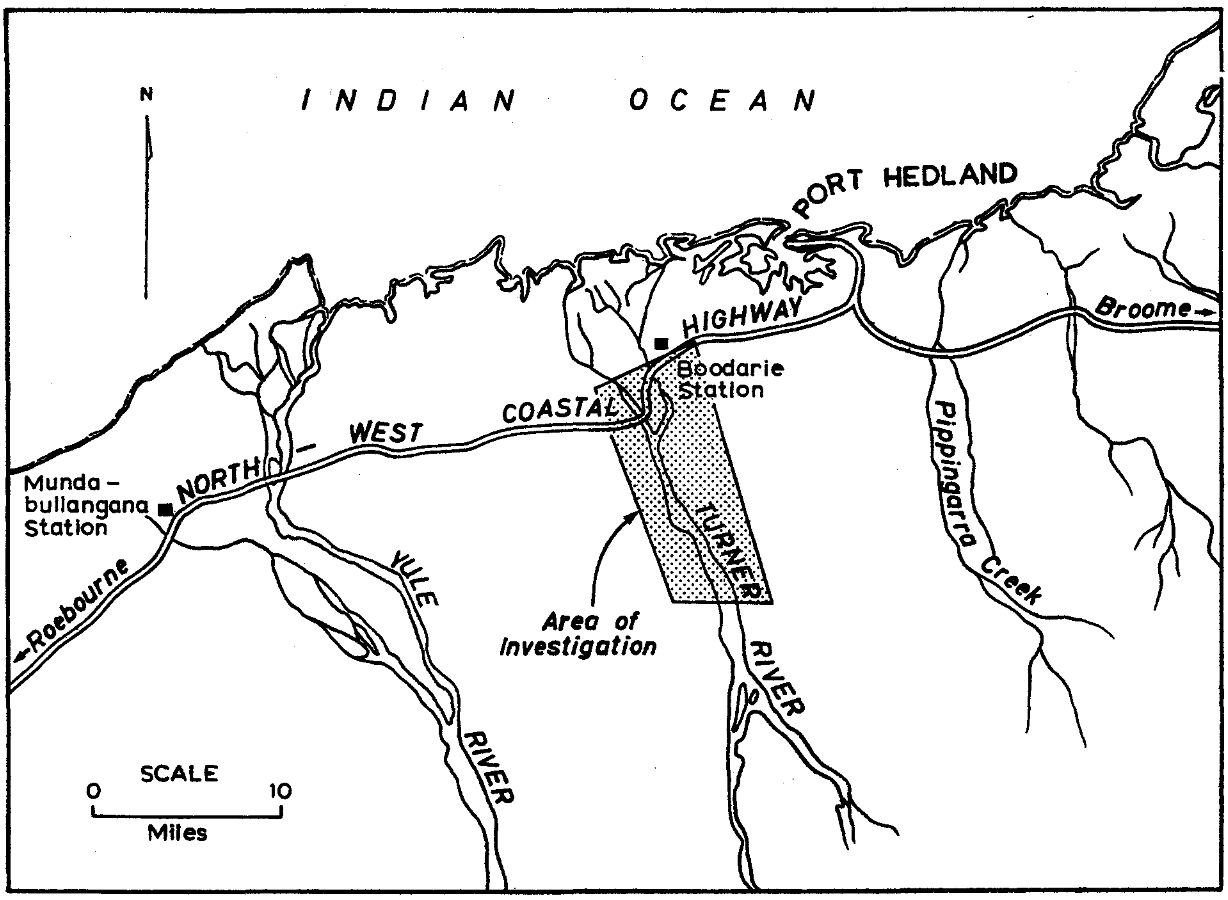


FIGURE 4 LOCALITY PLAN, TURNER RIVER AREA

The Turner River rises near Pullgunah, about 90 miles south-southeast of Port Hedland, and has a catchment area estimated to be 1,450 square miles.

Impersistent pools occur in the river bed after heavy rain or river flow; two months after the 1964/65 wet season, none remained. The river flows infrequently, and seldom reaches the P.W.D. pumping area. Surface flow was reported in 1961, 1965, and 1966. In 1965 the river flowed for a short time to a point 7 miles south of the highway. After heavy rain, P.W.D. sumps in the river bed sands fill with water, although there may be no river flow.

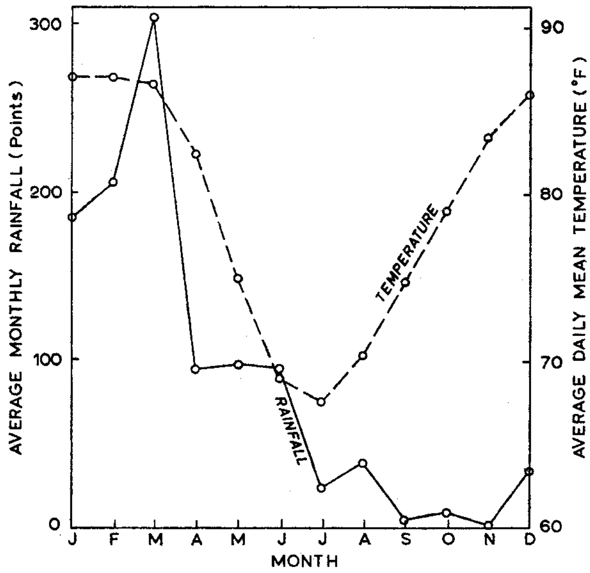


FIGURE 5: AVERAGE MONTHLY RAINFALL (30 year records) & AVERAGE DAILY MEAN TEMPERATURE FOR PORT HEDLAND

GEOLOGY

The geology is shown on the Port Hedland and Roebourne 1:250,000 Sheets (Low, 1965; Ryan, 1966).

Basement and its relationship to recent sediments

Three and a half miles east-southeast of Bore 14 outcrops of rectangularly jointed Archaean basic volcanics (Pilbara System, described as Warrawoona by Low) occur as a lens in the dominant Archaean granite and granite-gneiss.

Basement rocks encountered during drilling include the following types: pale-green aphanitic siliceous rock, quartz-feldspar-muscovite gneiss, hornblende - mica - gneiss, and quartz - feldspar tourmaline pegmatites. These rocks have thick weathering profiles, rich in kaolinitic clays and micas, of 35 to 75 feet thickness in Bores 2, 6, 8, and 16. In Bore 2, and in some P.W.D. production bores, the weathered bedrock zone contains the main aquifer. Siliceous horizons cemented with calcium carbonate (termed kunkar) are sometimes present in the weathered profile, having probably been secondarily introduced.

Drilling indicates that the basement floor is a northwards sloping undulating plain cut by a short northerly trending valley (Plate 9) beneath the present junction of the East and West Turner rivers, where thick alluvial sections have been penetrated.

Alluvium

The basement is covered by a wedge of alluvial and possibly eluvial material of poorly consolidated clay and sand, with minor gravel, thickening towards the north. Kunkar horizons are common in the alluvium. A maximum thickness of 145 feet of alluvium was cut in Bore 15. Bores penetrate a sandy-clay or clayey-sand surface layer 30 to 40 feet thick, below which is the aquifer zone. All strata contain high clay-silt fractions, and there are few " clean " sands or gravels. Bores on linear sand ridges also encounter sandy-clay-silt sections at depth.

The sediments are poorly sorted and the sphericity of sand grains is low. Quartz and feldspar sands are dominant, with minor jaspilite, chert, and siltstone fragments.

Kunkar layers occur below the water table. The kunkar has a calcium carbonate matrix, often hematised and with amorphous silica and dendritic manganese. Poorly consolidated highly calcareous clays and fine sands are common.

Correlation of strata between bores has not been found possible (Plate 8), because sedimentation in braided river channels subject to flash flows, produces lenticular strata. Later evidence from pump testing supports this view.

Strata samples from P.W.D. Bore 5, from 106 to 112 feet and 142 to 147 feet, were examined by H. S. Edgell. From the microflora, he considered them to be from a late Tertiary to Quaternary terrestrial-riverine deposit laid down during a period of lower sea-level.

GROUNDWATER HYDROLOGY

Drilling indicates thin clayey sand aquifers with a mean thickness 20 to 25 feet, the material including minor gravels and kunkar.

Water is cut at between 30 and 40 feet, apparently confined by the top sand-clay-silt layer. Unconfined water probably occurs in the poorly permeable materials above the aquifer zone, but is released too slowly to be detected in drilling.

The most productive aquifers may be kunkar layers, as bores yielding 2,000 to 3,000 gph have an abundance of kunkar in the aquifer. These good yields could perhaps be accounted for by the occurrence of solution channels in the kunkar.

Bore 2 (Plate 7 and 8) has a high yielding aquifer in weathered bedrock containing kunkar, and it is possible that the waters found in this zone and in the alluvium are connected, as they have similar chemical characteristics.

The curvature of the piezometric contours (Plate 7) indicates northerly movement of groundwater, apparently with a higher rate of flow along the line of the river than elsewhere. The steeper gradients on the flanks suggest decreased permeabilities in the alluvials away from the river. Downstream of the P.W.D. bore field, there is a distinct change in hydraulic gradient, the downstream one being approximately a fifth of that upstream. There are two possible reasons :

1. The area downstream of the bore field contains a thick section of alluvials, and there may be a permeability change in the vicinity, although this seems unlikely as yields upstream and downstream do not significantly differ.

2. More probably, pumping from the P.W.D. bores has altered the original gradient.

Cross section lines A and B (Plate 8) show that the piezometric surface slopes away from the Turner River, which must be the intake area. The depression in the piezometric surface around the P.W.D. bore field is a complex zone of depletion.

Plate 7 shows the static water levels in November, 1965. By March, 1966, there was a significant lowering of the water levels in 20 out of 22 observation bores. Changes of as much as 21 inches were observed in bores near the river (e.g., 8, 9, 15, 20, 12) indicating that the aquifers in this region are subject to the greatest fluctuations. This fall in water levels means a decrease in storage. The static water levels rose again after the river flowed in 1966.

SALINITY AND WATER QUALITY

During drilling, there was no significant change in water salinity with depth except that in some bores, a thin, very saline layer occurred at the top (e.g., Bore 4) probably caused by a rising water table leaching salts from the unsaturated zone. During the pump testing of some bores (e.g., Bores 4, 11), salinity decreased by as much as 40%. This probably means that a thin upper saline layer was intially drawn on, and later exhausted by pumping.

The isohalsine contour plan (Plate 7) is based on a mean, 'most-reliable' salinity for each bore. The 1,000 ppm isohalsine delineates the area of domestic quality water. An elongated freshwater body (less than 1,000 ppm) lies parallel to the river, again suggesting intake from this source.

The rapid increase of salinity north of the coastal highway is ascribed to sea water penetration of the alluvium, and the isolated freshwater bores, in small patches of coastal limestone, are fed by local rainwater.

Directly westward of the P.W.D. bore field, the isohalsines are closely spaced. Water too saline for domestic use occurs 1½ miles from the production bores (2,800 ppm in Bore 10).

The saline water re-entrant west of the P.W.D. bore field has two possible explanations:

1. The high salinities in Bores 10 and 20 may be partly spurious, because of unrepresentative sampling. A saline water layer, characteristic of the top of the aquifer, may have contaminated other samples from deeper aquifers during their collection, so increasing their salinity by 20 to 30%.

2. Aquifers in Bore 20, and to a lesser extent Bore 10, have a higher clay content than those in surrounding bores. Bore yields are correspondingly low.

The piezometric contours (Plate 7) reach a high point to the west of the P.W.D. bore field. This indicates that fresh water from the river intake is moving north, northeast, and northwest. The slow passage of water through the zone of low permeability is possibly responsible for the high salinities in Bores 10 and 20.

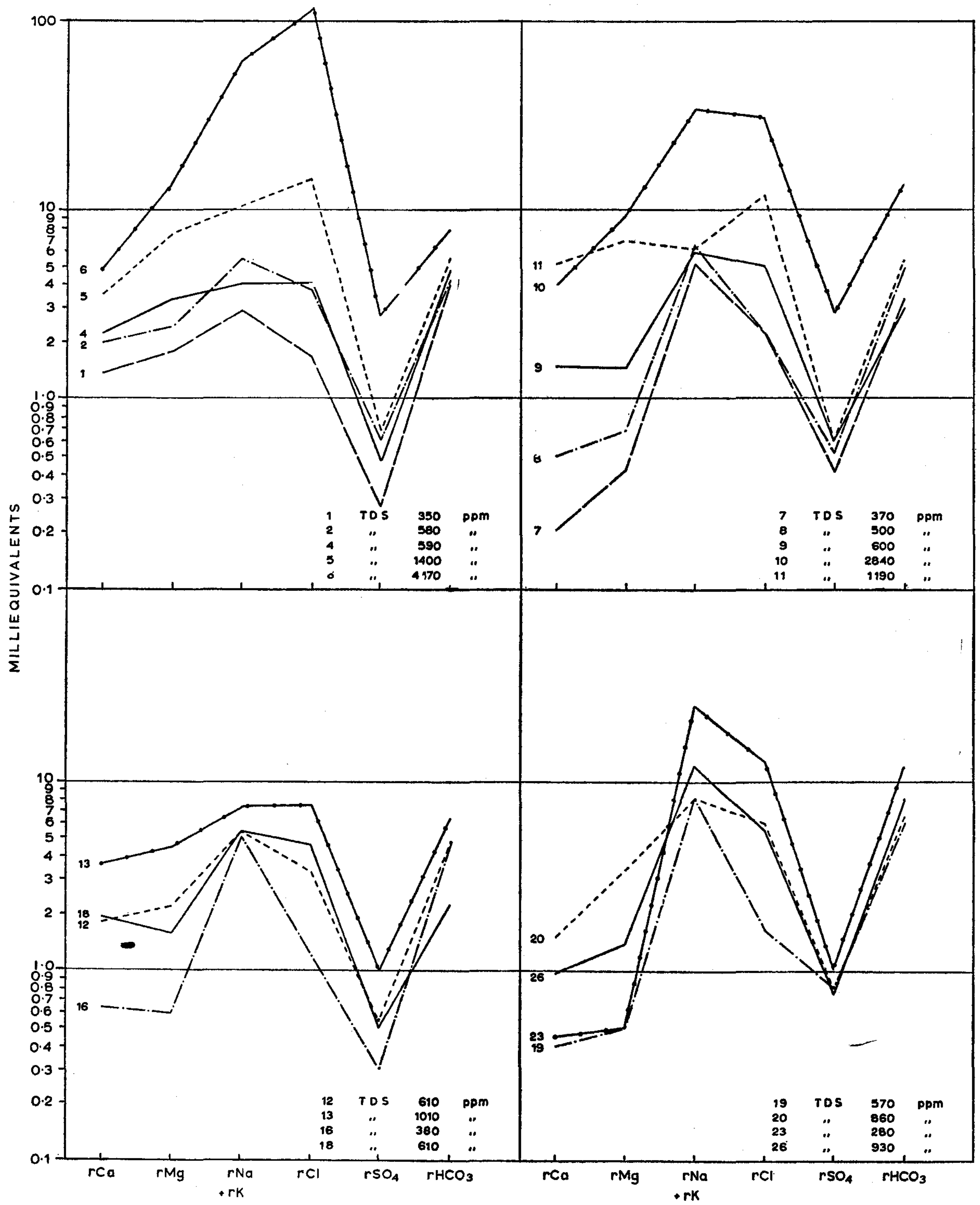


FIGURE 6 : SEMI-LOGARITHMIC GRAPHICAL REPRESENTATION OF CHEMICAL ANALYSES OF WATER FROM NUMBERED BOREHOLES

Analyses of the water from exploratory bores have been plotted on semi-logarithmic graph paper, using the Schoeller method (see Fig. 6) and the results suggest that:

1. Waters from weathered bedrock are chemically similar to those from alluvial aquifers, suggesting a hydraulic connection between basement and alluvium.
2. The saline interfluve waters are rich in chloride, sodium and bicarbonate ions.
3. All waters have high bicarbonate ion, and are neutral or slightly alkaline. This is probably caused by solution of calcium carbonate in waters percolating through kunkar in the alluvials.
4. In Bores 2, 4, 9, 12, and 18, total iron exceeds 0·3 ppm. Otherwise water samples conform to U.S. Public Health Service 1946 minimum standards (see Todd). All samples were odourless and usually colourless.

PUMP TEST RESULTS

Pump test results are shown in Table 1. In the southeast of the drilling area, Bores 3, 12, 23, and 14 were dry. Ten bores had supplies of less than 1,000 gph. All other bores had supplies of 1,000 to 3,000 gph except Bore 2, the yield of which exceeded 6,000 gph. This bore is unusual because the water comes from the weathered bedrock.

The lateral impersistence of the thin and clayey aquifers accounts for these pump test results, as even good aquifer materials may give small supplies (e.g., Bore 4) because of limited storage capacity.

Kunkar beds in the alluvium are fairly permeable, and may be the source of the moderate supplies (1,000 to 3,000 pgh) obtained from bores such as Nos. 5, 6, 7, 11, 13, and 15.

Drawdown-time data were plotted on semi-logarithmic scale, and there were certain general characteristics:

1. It is difficult to obtain a static drawdown level at a constant pump rate, because successive boundary conditions are reached during a long pumping test. The drawdown may remain static for several hours, and then rapidly decline, as occurred in Bore 5.

The original outputs of bores frequently cannot be duplicated if a new pump test is done after apparent recovery, and it is therefore difficult to determine the true yield of a bore.

This drawdown behaviour indicates the successive depletion of a series of impersistent aquifers, the progressive dewatering of which leads eventually to a decrease in pump rates, and failure to duplicate original yields.

2. Times of recovery to 90% of the original static water levels are usually less than 10 minutes (Table 1) but complete recovery times may be of very long duration, reflecting the restrictions imposed on groundwater movement by permeability changes and the frequent presence of lenses of clay and silt.

An analysis of semi-logarithmic graphs of drawdown against time, plotted for pump data on Bore 18, gave the following aquifer coefficients:

Transmissibility T = 2,365 gpd/ft
Permeability P = 94·6 gpd/ft^2

A modified non-equilibrium method, after Cooper and Jacob, 1946, was applied, assuming an aquifer thickness in Bore 18 of 25 feet. The semi-logarithmic graph of drawdown against time for pump data from other bores could not be used to obtain aquifer coefficients.

RECHARGE

The clayey subsoil is unlikely to allow appreciable direct rain water intake to the groundwater. Sand ridges are improbable recharge points because they overlie the clayey sand and silt.

Rainfall is concentrated into transient drainages joining clay pans or is used by plants in the soil zone. It is thought that direct intake will occur only if the broad river flats are widely flooded.

The shapes of the piezometric surface and the isohalsines indicate recharge through the river bed. It has been noted that this recharge is spasmodic and unreliable.

Bores 14, 23, and 12, which are within 3 to 4 miles of basement rock outcrop, are dry, suggesting that the alluvials are not being recharged by run-off along the bedrock-alluvium junction. However, recharge through the surface joints in the bedrock could occur.

ESTIMATES OF WATER RESERVES

Monthly water levels have been measured in observation bores from June 1965 to December 1966. Prior to April 1966 they were declining, as a result of groundwater flow to the north and extraction for the P.W.D. bore field. The Turner River had not flowed past the pumped bores since February 27, 1963 although in March 1965 a flow in the upper reaches was dissipated only 5 miles upstream of these bores.

From April to June 1966 the river flowed for about 3 months after heavy rain. Water levels rose at nearly every observation point although the duration and magnitude of the rises differed. In most places they had reached maxima by

Table 1

PORT HEDLAND TOWN WATER SUPPLY, TURNER RIVER EXPLORATORY DRILLING, SUMMARY OF PUMP TEST RESULTS

Bore No.	Depth	SWL	Available drawdown	Draw-down	Suction depth	Pumping rate	Duration	RECOVERY TIME to 90% SWL		RECOVERY TIME Complete	
	feet	feet	feet	feet	feet	gph	hours	min.	sec.	min.	sec
1	80	34.3	30	>20	58	<200	½	2	30	3	45
*2	111	59.5	35.5	4.5	90	5,800	5½		15	3	15
4	84	30.75	53?	6.3	75	600	7½	3	00	3	30
5	90	29.4	45	22.4	76	1,570	13		55	1	30
6	149	29.5	43	22.4	74	1,250	8	1	40	3	00
7	114	25.6	84	38	68	2,800	15½	9	00	>30	00
8	133	24.7	35	19	58	2,000	4½	....		4	30
9	102	33.9	27	26	....	1,200	4½	....		>15	00
10	104	31.7	37	23	61	<200	½	13	00	28	00
11	64.5	31.6	32	10.9	55	1,960	20	2	00	20	00
12	86.5	50.7	34	12 +	....	<200	⅓	....		6	00
13	75.6	35.4	25	16.5	62	1,650	8	1	30	2	45
15	152	30.5	30	27.6	64	1,890	8	>4	30	>30	00
16	112	36	44?	36.6	76	480	8	2	30	5	00
17	107	20.9	55?	27.6	62	960	9	70% recov- in 3 min.		∞	
18	104	47.9	32?	28.5	95	860	9	....		8	45
19	92	29	60?	43.7	82	800	9	7	30	∞	
20	132	29.5	20	?	....	500	½	....		....	
26	110	48.5	22	19	....	<400	⅓	....		....	

* 5,800 gph was maximum pump capacity. Bore should be tested with higher capacity pump.

early December 1966 but a few were still rising. The displacements (as much as 10·5 ft) were greatest in bores near the river. The rate of water level rise was also greatest in these bores.

Changes in storage in the aquifer during the periods of decline and recharge are estimated from the water levels. Data on the pumpage from the bore field have been provided by the Public Works Department. Estimates of the flow of groundwater through a section C-D (Plate 7) across the river are based on the value of permeability 95 gal/day/sq ft calculated from the test pumping of Bore 18. The actual mean permeability may differ from that assumed in the calculations that follow, because the nature of the aquifer under the river is not known.

1. *Subsurface flow*

As shown on Plate 7 and Figure 7 the piezometric surface has been depressed around the pumping field. Within a certain area open to the south along the Turner River, water is drawn towards the pumping bores, whereas outside this area it flows to the northwest, north, and northeast. Its northern part is outlined on Plate 7, and is referred to as the area of draw.

All of the groundwater entering the area of draw between periods of river flow moves through the section C-D, which is 1.9 miles wide and situated between Bores 1 and 4. The hydraulic gradient across the section is 6·9 feet per mile. A mean aquifer thickness of 30 feet is assumed, and a permeability of 95 gal/day/sq ft.

Inflow = area of cross section x permeability x hydraulic gradient
= 30 x 1·9 x 95 x 6·9 gal/day
= $3{\cdot}74 \times 10^4$ gal/day (approx.)

2. *Reduction of storage between periods of river flow*

Water levels measured over periods of 7 to 9 months from June, July or August 1965 to March 1966 in six bores in and near the area of draw are used to estimate the average decline over that area. The changes in level are listed in Table 2. Bores 8 and 10 exhibit anomalous results which are nevertheless included in the calculations.

Average decline in eight months: 1.5 feet (approx.)

The area of draw covers approx. 8 square miles.

Therefore volume of aquifer dewatered over 8 months = $1{\cdot}5 \times 8 \times 5{,}280^2$ cu ft
= 335×10^6 cu ft (approx.)

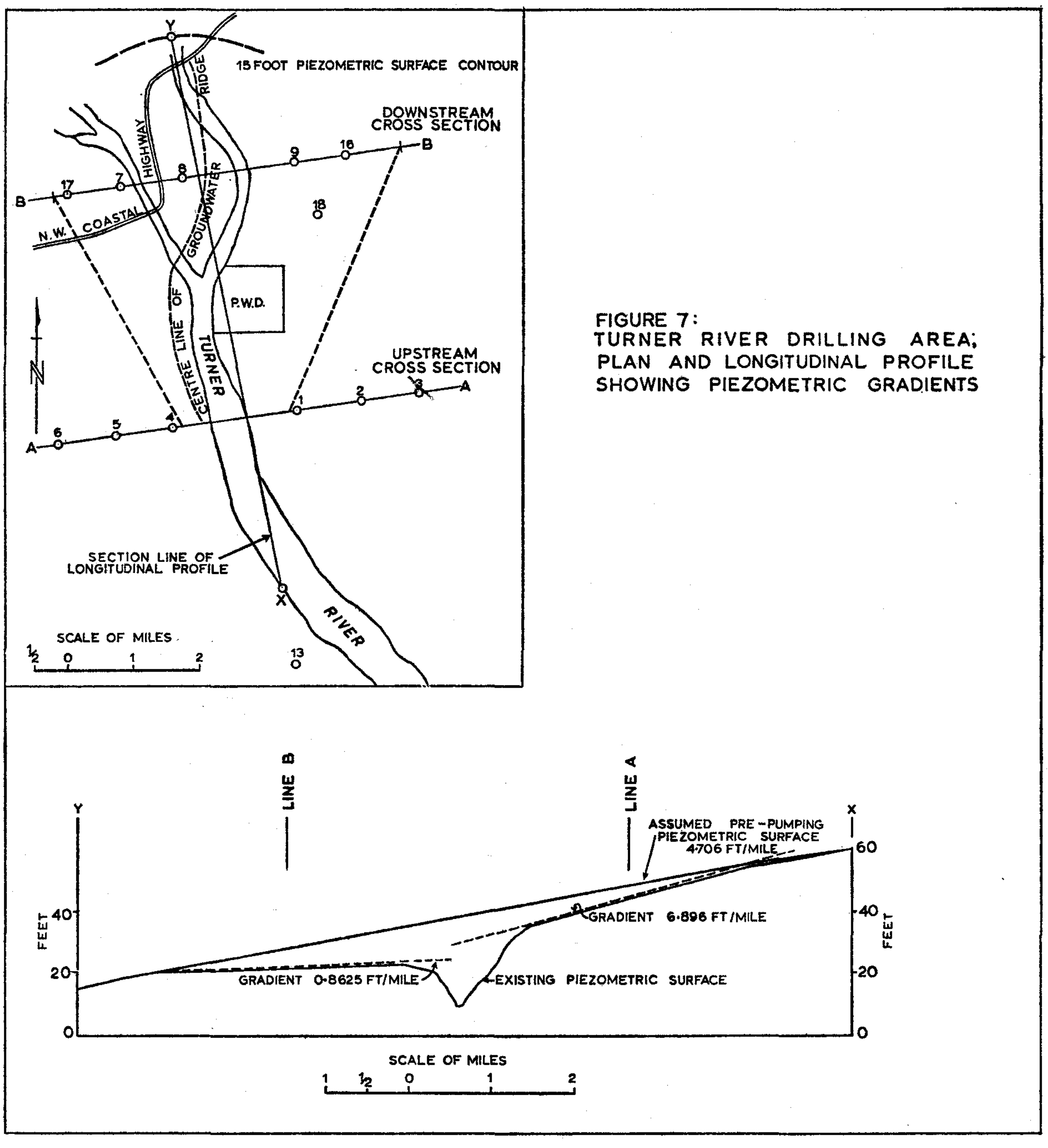


FIGURE 7: TURNER RIVER DRILLING AREA; PLAN AND LONGITUDINAL PROFILE SHOWING PIEZOMETRIC GRADIENTS

Table 2
DECLINE IN WATER LEVELS IN SIX BORES BEFORE THE 1965–66 RIVER FLOW

Bore No.	Date	SWL	Date	SWL	Decline	Period
		ft		ft	ft	months
1	June 65	35.67	Mar. 66	37.38	1.71	9
4	July 65	31.46	Mar. 66	32.71	1.25	8
8	June 65	24.27	Mar. 66	27.88	3.61	9
9	June 65	34.77	Mar. 66	36.56	1.79	9
10	July 65	34.46	Mar. 66	34.29	+0.17	8
18	Aug. 65	48.42	Mar. 66	49.75	1.33	7

3. *Extraction of groundwater*

During the 8 months from July 1965 to March 1966, water was pumped at the average rate of 0·208 x 10^6 gal/day.

Inflow has been calculated (above) to be 3·74 x 10^4 gal/day.

Therefore the net extraction from storage was 0·171 x 10^6 gal/day i.e., 41·6 x 10^6 gal or 6·78 x 10^6 cu ft over 8 months.

Then, as the change in storage is 335 x 10^6 cu ft (see 2 above), the storage coefficient = $\frac{6{\cdot}68 \times 10^6}{335} = 0{\cdot}02$

4. *Recharge*

The rises in water levels in eight bores in and near the area of draw in the 9 months March to December 1966 are listed in Table 3. They average 5·1 feet. It is assumed that the area of draw is approximately the same as before recharge took place, that is 8 square miles.

Volume of aquifer resaturated
= 8 x $5{,}280^2$ x 5·1
= 1,140 x 10^6 cu ft

With the storage coefficient of 0·02, the volume of recharge = 0·02 x 1,140 x 10^6 x 6·23 gal
= 142 x 10^6 gal

Pumpage continued during the period of recharge.

Using the pumping rate from the previous 9 months, the total abstraction was 272 x 0·208 x 10^6 gal = 56·6 x 10^6 gal

Total recharge = change in storage + pumpage
= 142 x 10^6 + 56·6 x 10^6 gal
= 199 x 10^6 gal

At the present pumping rate the net extraction of water (pumpage – inflow) over one year = 365 x 0·171 x 10^6 = 62·4 x 10^6 gal. The recharged water would therefore last $\frac{199 \times 10^6}{62{\cdot}4 \times 10^6}$ = 3.2 years.

Table 3
RISES IN WATER LEVELS IN EIGHT BORES AFTER THE 1966 RIVER FLOW

Bore No.	SWL Mar. 3, 1966	SWL Dec. 5, 1966	Increase
	ft	ft	
1	37.38	34.67	2.71
4	32.73	28.54	4.19
8	27.85	17.31	10.54
9	36.56	30.50	6.06
10	34.29	29.56	4.73
18	49.75	48.25	1.50
TR2	36.94	34.60	2.34
TR8	38.81	30.33	8.48

Plotting of the rises in water level, after recharge occurs, shows that a relatively quick initial rise takes place, the curve gradually flattening and then slowly declining. In the 4 months prior to the river flow, the same levels, measured in the 14 bores listed in Table 4 scattered over the whole area of investigation had an average decline of 0·75 feet in 4 months, or 0·19 feet per month. Since the figure of 0·19 applies to the end of a cycle, admittedly not an extremely severe one, it has been assumed with some validity that the rate of decline will probably never greatly exceed this figure. In the calculation which follows, the figure of 0·19 feet decline per month, which represents the depletion rate arising from both pumpage and natural outflow, will therefore give a value rather less than the real one for the total time it would take to consume the amount of recharge added by each river flow.

As pumpage and outflow continued all through the recharge period, which in this case was about 9 months, the theoretical depletion, at the constant rate indicated by the figure of 0.19 feet per month would have been 0.19 x 9 = 1·71 feet. Recharge made good this loss as well as producing the water level rises, which average 4·5 feet for all the bores in the area, including the area of draw (Tables 3, 4). Therefore total recharge, in terms of water levels, is 4·5 + 1·7 = 6·2 feet.

But when no recharge is taking place, the decline in water level at the rate of 0·19 feet per month would cause a drop in the water level of 0·19 x 12 = 2·3 feet per year.

But since the 1966 flood was theoretically equivalent to a total rise of 6·2 feet, the addition it made to storage would be completely consumed in $\frac{6{\cdot}2}{2{\cdot}3}$ years = 2·7 years. This is of the same order as the figure of 3·2 years calculated in section 4 above, but is lower, probably for the reasons discussed.

Table 4
RISES IN WATER LEVELS IN AN ADDITIONAL FOURTEEN BORES AFTER THE 1966 RIVER FLOW

Bore No.	SWL Mar. 3, 1966	SWL Dec. 5, 1966	Increase
	ft	ft	
2	61.23	61.44	— 0.21
5	31.50	27.94	3.56
6	31.08	29.42	1.66
7	28.10	19.52	8.58
11	32.75	30.29	2.46
12	53.42	47.73	5.69
13	37.33	33.79	3.54
15	32.65	26.21	6.44
16	38.50	35.00	3.50
17	23.46	16.83	6.63
19	30.12	23.29	6.93
20	32.44	25.25	7.19
23	41.83	41.04	0.79
26	49.29	47.98	1.31

When recharge takes place in a similar manner to that of 1966, in which the river flowed for 3 months, the addition to storage would last for just over 3 years, after which the base storage of the aquifer would be depleted. In practice, the volume of recharge may vary according to the length of time for which the river flows; the life of the recharged water would vary in the same way. There are no long-term records of the frequency of river flow, but over the last few years the river appears to have flowed often enough to replace the water being extracted at the present rate.

However, droughts of more than 3 years have been reported.

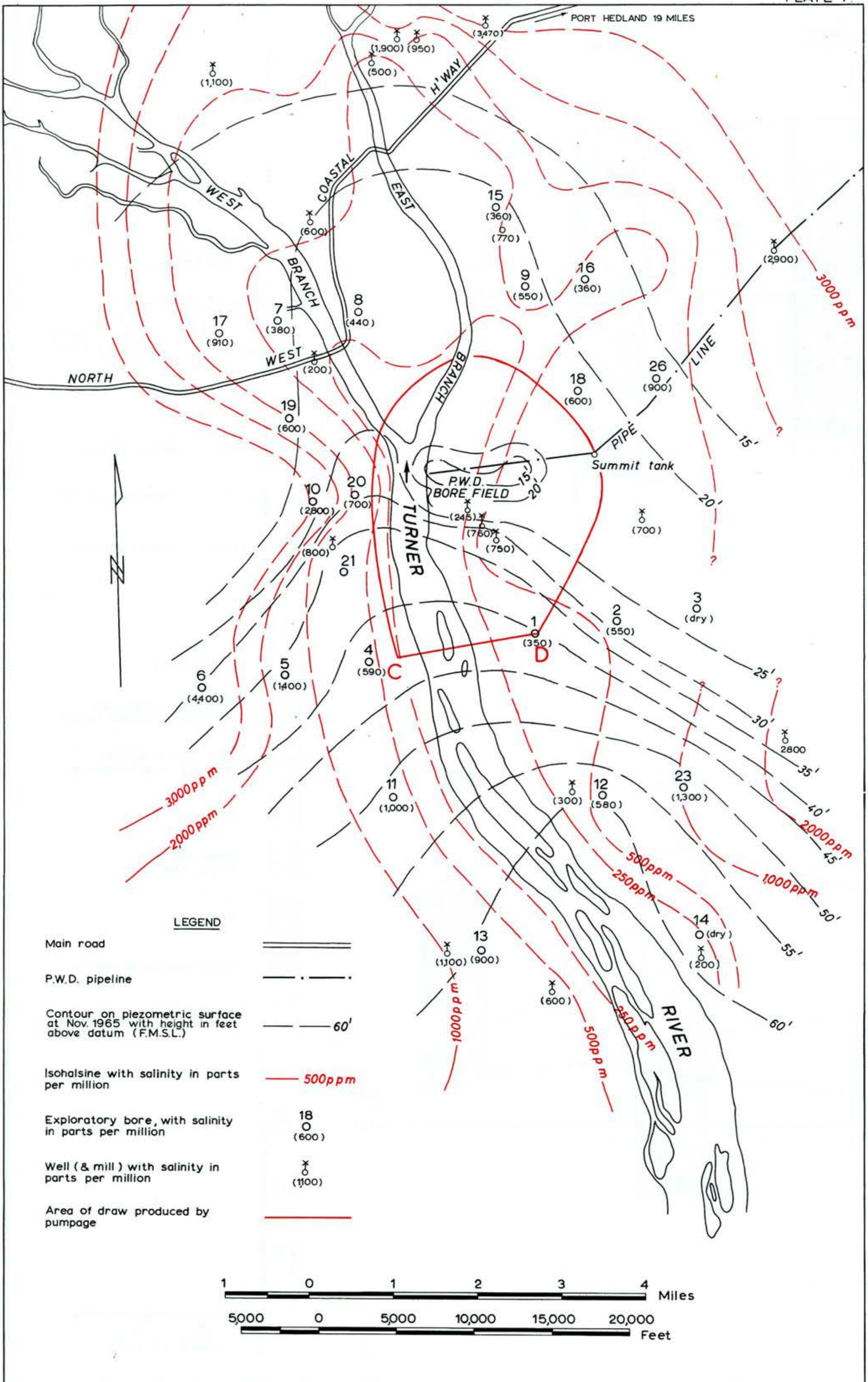
CONCLUSIONS

1. The available aquifers are thin, clayey, and of limited extent, and their recharge is irregular.

2. If a comparable flow to that of 1966 takes place once every 3 years, the present rate of pumping can be maintained without drawing on base storage. If no recharge occurred for more than 3 years, storage would be depleted by pumping, and the freshwater body mined. Overpumping could result in a salinity increase in the bore field, and it is recommended that the present rate of abstraction should not be increased.

3. An increase in the area of draw, by wider bore distribution, could more effectively utilise water available from recharge. Owing to poor permeabilities, the choice of new sites is probably limited to the vicinity of Bores 2, 7, and 8.

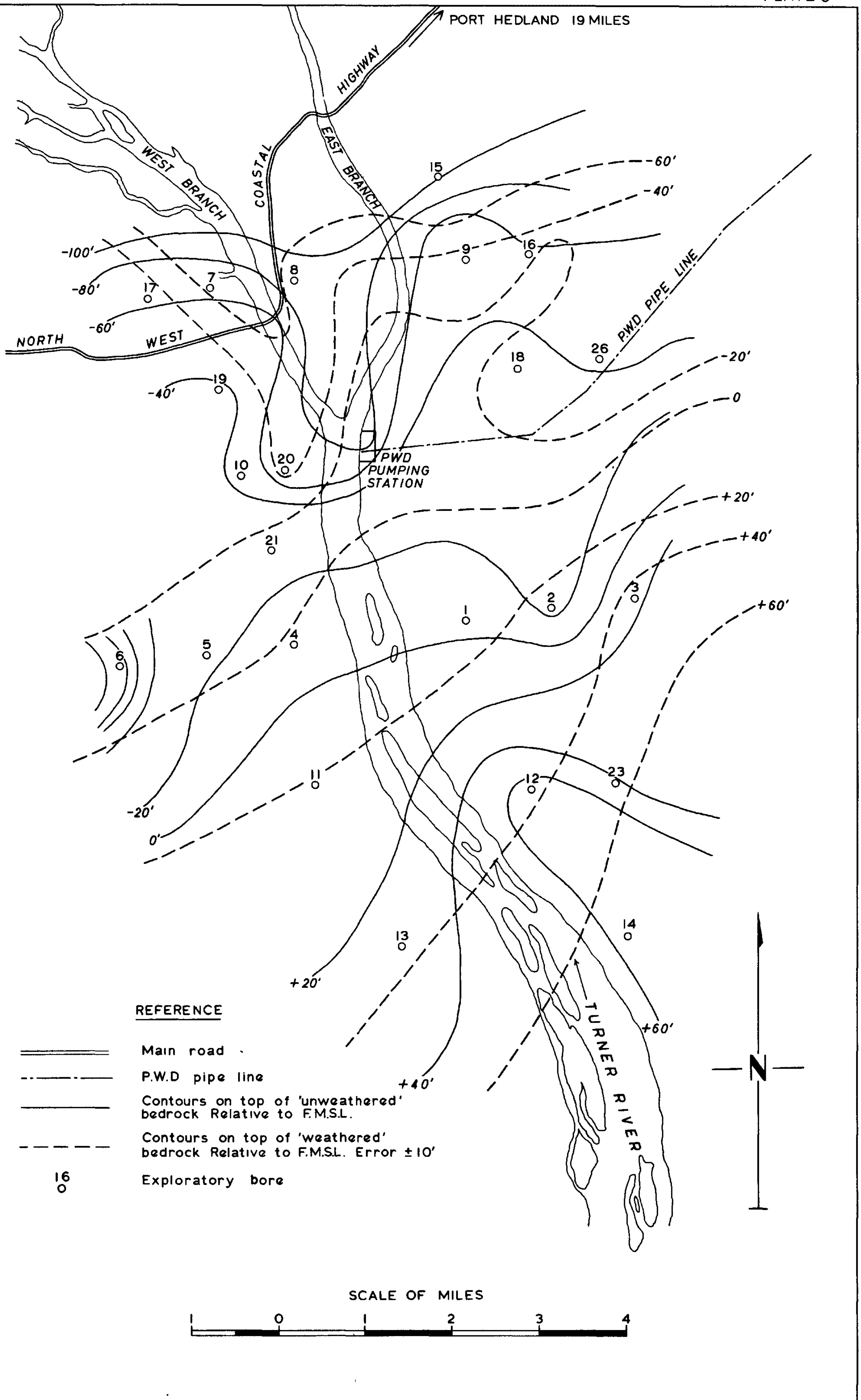
4. Static water levels in all bores should be taken monthly in the future. This will provide information on the extent of river recharge and



TURNER RIVER DRILLING AREA SHOWING CONTOURS ON PIEZOMETRIC SURFACE AND ISOHALSINES

To accompany report by R. Farbridge, 1966

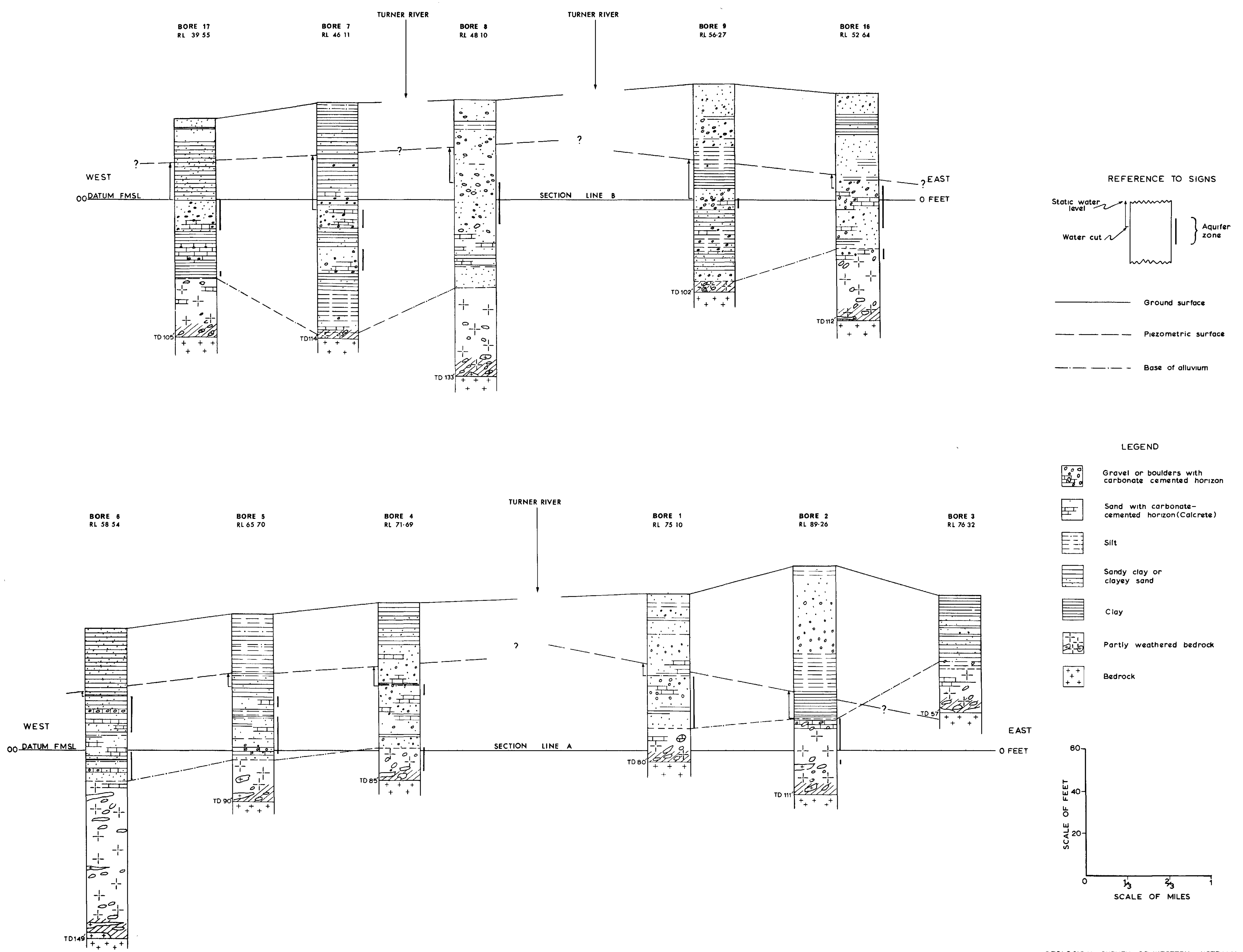
9745



TURNER RIVER DRILLING AREA
CONTOURS ON BASE OF ALLUVIAL MATERIAL AND ON TOP OF UNWEATHERED BEDROCK

To accompany report by R. Farbridge, 1966

PLATE 8



GEOLOGICAL SURVEY OF WESTERN AUSTRALIA

TURNER RIVER AREA
CROSS SECTIONS A AND B

To accompany report by R Farbridge, 1966

9226

will help to determine the long term behaviour of the piezometric surface relative to the P.W.D. bore field. Detailed records should be kept of the periods during which river flow takes place. Future salinity checks, particularly on Bores 10, 18, and 20, are desirable to detect any salinity increases.

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EXPLORATORY DRILLING FOR UNDERGROUND WATER, GINGIN BROOK AREA, PERTH BASIN

by C. C. Sanders

ABSTRACT

Six exploratory water bores were drilled across the Perth Basin from Gingin to the west coast. The maximum depth drilled was 2,610 feet and Jurassic sediments were the oldest encountered.

Three aquifers were recognised in the Mesozoic rocks, but there was no test pumping. Domestic quality water is restricted but there is ample stock quality water. The Quaternary sediments form an extensive, shallow, unconfined aquifer, which probably contains a substantial quantity of domestic quality water.

INTRODUCTION

This exploratory drilling is part of a long-term investigation of the hydrogeology of the Perth Basin, and was done by the Mines Department between May, 1965 and August, 1966. About 50 miles north of Perth, six rotary bores were drilled across the Perth Basin from Gingin in the east to Guilderton in the west, a distance of about 25 miles.

Gingin Brook Bores 1 to 4 were on a line extending in a westerly direction from near Gingin, and spaced at intervals of 7 to 9 miles. Subsequently Bores 5 and 6 were drilled in the centre of the line.

Palynological determinations were made from core and sludge samples by B. S. Ingram and B. E. Balme, whose work is gratefully acknowledged.

PHYSIOGRAPHY

The area is on the coastal plain near the middle of the Perth Basin, and is bounded on the east by the Darling Fault and on the west by the coast. A plateau of late Mesozoic rocks about 10 miles wide abuts against the Darling Fault 8 miles east of Gingin, and near Gingin townsite this plateau has been largely eroded by Gingin Brook and its tributaries. Two miles to the west, an escarpment appears to be the physiographic expression of a concealed fault downthrown to the west and trending N24°W. Westward of this escarpment a plain of low relief dips gently seaward, forming a northern extension of the Swan Coastal system described by McArthur and Bettenay (1960). The natural drainage lies along the valleys of the Moore River and Gingin Brook.

DRILLING AND TESTING PROCEDURES

Drillhole cuttings were collected every 10 feet, and cores were cut mainly in clayey horizons at intervals of about 200 feet.

Gamma ray, spontaneous potential, long and short normal resistivities, and point resistivity logs were run at 1,000 feet depth and at total depth. In addition, Bore 2 was logged by Schlumberger Seaco Inc. for WAPET. Lithologic boundaries were fixed and sites for formation tests were determined from the gamma ray log. The long normal resistivity log proved useful for computing the salinity of formation water using the results of drill stem tests as calibration points and selecting a formation factor of six.

Water samples were collected with a Johnston Formation Tester. Results were often disappointing as in some cases poorly consolidated sediments were drawn into the tester and blocked the bottom choke, and the sometimes low static water levels caused contamination of formation water by drilling fluid in the drill stem. Uncontaminated water samples were submitted to the Government Chemical Laboratories for standard analyses and these are summarised in Table 4.

GEOLOGY

STRATIGRAPHY

McWhae and others (1958) describe the extensive and essentially continuous continental deposition which occurred in the Perth Basin during the Upper Jurassic and Lower Cretaceous epochs. A period of tectonism associated with local movement on the Darling Fault Zone followed, establishing shallow marine conditions over much of the central Perth Basin by Upper Cretaceous times, followed by regional emergence during the Tertiary period.

A thick Mesozoic succession and a thin veneer of Quaternary sediments were intersected during drilling. The Upper Jurassic and Lower Cretaceous beds correlate with the Yarragadee Formation farther north, and with the South Perth Formation near Perth and Bullsbrook. For the sake of uniformity of nomenclature with recent work in the Perth Basin (Pudovskis, 1962; Lowry, 1965), the Upper Jurassic—Lower Cretaceous section is herein referred to as Yarragadee Formation.

In this report this formation is divided into two units, partly on palynological grounds but also from lithological considerations. The result is that Units I and II shown in Table I below correspond with Zones A and B-C of Ingram (1967). He has been able to subdivide Unit II into two floral zones B and C, but this has little lithological expression except in the western segment of the drilled area where a possible disconformity has been recognised.

Table 1

SUBDIVISION OF THE YARRAGADEE FORMATION, GINGIN BROOK

Unit	Palynological Zone (Ingram, 1967)	Stage	Lithology
II	Zone C	Neocomian—Aptian	Interbedded carbonaceous claystone and sandstone (Bores 1, 2, 3, 4, 5 and 6)
		Possible local disconformity	
	Zone B	? Neocomian	Thick sandstone and thin claystone with occasional calcareous beds (Bores 2, 3 and 6)
		Disconformity	
I	Zone A	Tithonian—Neocomian	Non-marine sandstone and carbonaceous claystone (Bores 2 and 3)

A doubtful lithologic break marks the Upper Jurassic—Lower Cretaceous boundary, but this cannot yet be defined accurately on palynological evidence.

The Middle Cretaceous is represented by the Osborne Formation, and the Upper Cretaceous by the Molecap Greensand, Gingin Chalk, and Lancelin Beds. The last mentioned unit was proposed by Edgell (1964) for Campanian age marine strata recognised in bores at Lancelin.

The Quaternary sediments consist of eolian Coastal Limestone.

Mesozoic statigraphic correlations are shown in Table 2.

UPPER JURASSIC

Yarragadee Formation Unit I

The predominantly non-marine Upper Jurassic sediments are correlated with the Yarragadee Formation of the central and northern Perth Basin, and possibily with the Claremont Sandstone in the Perth area. Balme (pers. comm.) has identified long ranging Upper Jurassic—Lower Cretaceous microflora from Bores 2 and 3. The assemblages contain no typically Cretaceous forms and the associations of species are more characteristic of Upper Jurassic than Cretaceous sediments, but the palynomorphs appear younger than those from the type section of the Claremont Sandstone.

Typically the Upper Jurassic sequence consists of alternating bands of sandstone and grey claystone, pyritic in places, with indeterminate plant remains and lignite. The sandstone is light grey, fine to medium-grained, clayey, and composed of well sorted, subrounded grains of quartz and minor feldspar. Garnet is a common accessory mineral. The claystone is dark grey, often carbonaceous, well indurated and hard, but rarely banded.

Upper Jurassic sediments were intersected in Bores 2 and 3 but were not fully penetrated, the maximum penetration being 870 feet in Bore 3. The section consists of thick sandstone and claystone giving a characteristic blocky graph for the gamma ray log.

The beds are non-marine, formed in a swampy, lacustrine environment by continuous deposition of alternating strata, resulting from frequent inundation by terrigenous mud and clastic material derived from the Precambrian plateau to the east.

Upper Jurassic sediments were intersected below 2,410 feet in Bore 2. The sequence is of interest because geophysical evidence suggests a major unconformity at a depth of about 2,000 feet thought to represent the Lower or Middle Jurassic and the Upper Jurassic boundary.

Palynological evidence indicates a sedimentary break between 2,010 feet and 2,495 feet, but it is unlikely that the hiatus is of comparable magnitude to that occurring in bores to the south of Perth, where Lower Cretaceous rests on Lower Jurassic sediments. It seems likely that the bore did not go deep enough to reach the unconformity (Plate 10).

LOWER CRETACEOUS

Yarragadee Formation Unit II

The Lower Cretaceous succession is equivalent to the South Perth Formation of Fairbridge (1953) and the upper part of the Yarragadee Formation described by McWhae and others (1958).

The unit is a sequence of interbedded, mainly non-marine sandstone, siltstone, and claystone with very common lignite and garnet. Thin calcareous beds occur frequently but are not laterally persistent across the basin.

Seismic evidence from the middle of the drilled area shows that the formation has a regional eastward dip of about two degrees. Correlation between the bores is difficult and it is likely that numerous large interconnected swamps covered the area during deposition.

The greatest thickness of section, 2,260 feet, was penetrated in Bore 2 where it is feldspathic, micaceous, pyritic, and carbonaceous and consists of alternating sandstone, siltstone, and claystone. The sandstone is light grey, medium to coarse-grained ; the grains are moderately sorted and are subangular to subrounded. The siltstone and claystone are dark grey, soft, and puggy. A deepening of the basin towards the east is indicated in Bore 5. The sequence here is marked by an influx of fine terrigenous material particularly garnet, the presence of carbonaceous matter, and the frequence of calcareous beds which are chemical and syngenetic in character.

Thick arkosic sands are interspersed with minor clay and silt from 60 to 265 feet in Bore 5. Below 265 feet the sequence is predominantly a uniform siltstone. The gamma ray log of the Gingin town bore situated about one mile to the east indicates a possible correlation of the sands between 360 and 455 feet with those occurring between 174 and 265 feet in Bore 5. This suggests that the sediments are dipping at about two degrees to the east.

In Bore 1 near the Darling Fault zone the facies consists of shale and claystone with minor sandstone. The shale is variably coloured, mainly grey to dark brown, micaceous, carbonaceous, pyritic, and exhibits prominent lamination. The bands, in a core sample taken at 1,000 feet, dip at about 5°. The dip direction is probably eastward.

The sandstone is grey, medium to very coarse-grained, consisting of subrounded, poorly sorted quartz and granitic fragments.

The sequence in Bores 4 and 6 consists of alternating thin lenses of sandstone and claystone. The section was deposited in a marginal marine environment and is characterised by a lack of calcareous strata. Marine influences are more pronounced in Bore 4, indicating that marine incursions were generally restricted to the west of the drilled area.

The section in Bore 4 consists of feldspathic sandstone interbedded with dark grey carbonaceous claystone and siltstone. The claystone is micaceous, uniform in texture, generally well indurated and lacks bedding or lamination. Lignite and pyrite are common accessory minerals. The sandstone sequence thickens below 1,100 feet and consists of coarse to medium-sized quartz and feldspar grains, subangular in shape and poorly sorted.

In Bore 6 the sequence is mainly non-marine with minor paralic intercalations which reach a maximum development at about 1,800 feet. The strata are thinly interbedded sandstones,

Table 2

JURASSIC AND CRETACEOUS CORRELATIONS IN PERTH BASIN, WESTERN AUSTRALIA

System	Series	Stage	Geraldton* Mingenew	Dandaragan* Gingin	Gingin (Proposed herein)	Perth Area*
CRETACEOUS	UPPER	Maestrichtian				
CRETACEOUS	UPPER	SENONIAN: Campanian		Poison Hill Greensand	Poison Hill Greensand Lancelin Beds	
CRETACEOUS	UPPER	SENONIAN: Santonian		Poison Hill Greensand	Poison Hill Greensand Lancelin Beds	
CRETACEOUS	UPPER	SENONIAN: Coniacian		Gingin Chalk	Gingin Chalk	
CRETACEOUS	UPPER	Turonian		Molecap Greensand	Molecap Greensand	Molecap Greensand
CRETACEOUS	UPPER	Cenomanian		Dandaragan Sandstone		
CRETACEOUS	LOWER	Albian			Osborne Formation	Osborne Formation
CRETACEOUS	LOWER	Aptian			Possible Hiatus	Possible Hiatus
CRETACEOUS	LOWER	Neocomian			Yarragadee Formation Unit II	South Perth Formation
JURASSIC	UPPER	Tithonian	Yarragadee Formation	Strathalbyn Sandstone or Bullsbrook Beds	Yarragadee Formation Unit I	South Perth Formation
JURASSIC	UPPER	Kimmeridgian	Yarragadee Formation	Yarragadee Formation	Yarragadee Formation	Claremont Sandstone
JURASSIC	UPPER	Oxfordian	Yarragadee Formation	Yarragadee Formation	Yarragadee Formation	Claremont Sandstone
JURASSIC	MIDDLE	Callovian	Yarragadee Formation	Yarragadee Formation	Yarragadee Formation	Claremont Sandstone
JURASSIC	MIDDLE	Bathonian	Yarragadee Formation	Yarragadee Formation	Yarragadee Formation	Claremont Sandstone
JURASSIC	MIDDLE	Bajocian	Kojarena Sandstone Newmarracarra Limestone Bringo Shale Colalura Sandstone	Cadda Formation Cockleshell Gully Sandstone	Cadda Formation Cockleshell Gully Sandstone	Claremont Sandstone

* McWhae and others, 1958.

claystones, and siltstones. A minor hiatus is indicated at 2,070 feet, between a predominantly dark grey, micaceous siltstone sequence below and the sandstone-claystone succession above.

This sedimentary break is recognised by Ingram (1967) as the boundary between his floral zones B and C.

UPPER CRETACEOUS

The Upper Cretaceous is represented by the Osborne Formation, Molecap Greensand, Gingin Chalk, and Lancelin Beds.

Osborne Formation

The Osborne Formation (McWhae and others, 1958) occurs in Bores 1, 4 and 6 where it rests disconformably on Unit II of the Yarragadee Formation. The sequence is typically a dark green to black, glauconitic, carbonaceous claystone. The presence of glauconite and frequent microplankton in core samples indicates shallow marine deposition.

The formation attains its maximum thickness of 343 feet in Bore 6, thinning westwards to 315 feet in Bore 4. Between Bores 3 and 6 the formation is apparently faulted out by a normal fault with a westerly downthrow of at least 2,000 feet (Plate 10).

In Bore 1 the Osborne Formation is only 250 feet thick but its base is 64 feet above sea level, and 510 feet higher than at Bore 6. Near Gingin the formation is absent and has apparently lensed out between the town bore and Bore 1.

The age of the Osborne Formation in the Gingin Brook bores is Albian—Cenomanian (B. Ingram).

Molecap Greensand

The Molecap Greensand (Fairbridge, 1953) was penetrated only in Bore 1 where it unconformably overlies the Osborne Formation. The unit attains a thickness of about 50 feet in the bore and is thought to be Coniacian in age.

Gingin Chalk and Lancelin Beds

Upper Cretaceous calcareous strata of Santonian to Campanian age were penetrated by Bores 4 and 6.

On lithological grounds the succession may be divided into two units. The lower silty limestone unit containing *Inoceramus* fragments was penetrated between 180 feet and 215 feet in Bore 4. It contains abundant foraminifera which A. E. Cockbain (pers. comm.) considers similar to specimens from the type section of the Gingin Chalk, near Gingin. He tentatively suggests that this unit is of lowest Campanian age, but a Santonian age for the strata from 200 feet to 210 feet could not be ruled out.

The upper unit, a calcareous, glauconitic siltstone occurring between 130 feet and 180 feet in Bore 4 is considered by Cockbain to be definitely Campanian in age and to correlate with the Lancelin Beds (Edgell, 1964). Lithologically the sequence is similar to the Lancelin Beds which are grey marls containing abundant fragments of *Inoceramus*, and is atypical of the Gingin Chalk which is a pure white chalk.

In Bore 6, 70 feet of calcareous siltstone was penetrated. Cockbain assigned a Santonian—Campanian age to these strata, but the two could not be differentiated with any confidence.

Quaternary succession

Quaternary eolian limestone and dune sands rest unconformably on Upper and Lower Cretaceous sediments over much of the western area and border the present-day coast, reaching at least 114 feet in thickness in the Guilderton town bore.

The level of the Quaternary—Cretaceous unconformity rises gently from about 80 feet below sea level at Guilderton to 10 feet above sea level in Bore 2, disappearing altogether at the Upper Cretaceous escarpment 3 miles west of Gingin.

TECTONIC HISTORY

For many years the Perth Basin was thought to have a gentle basinal structure, deepest in the middle and shallowing towards the north and south. Recent exploratory drilling for oil and water has shown the region to be one of tectonic complexity.

At a depth of about 2,000 feet a major seismic unconformity resembling a marine scarp is suggested by geophysical work undertaken by WAPET. The feature is thought to mark the junction between the Lower or Middle Jurassic and the Upper Jurassic. Bore 2, (total depth 2,495 feet) was sited above the crest of the unconformity, but on palynological evidence, apparently failed to penetrate it.

A thick Upper Jurassic—Lower Cretaceous paralic to non-marine section was deposited above the unconformity as a result of renewed movement along the Darling Fault zone. This produced an uneven subsidence of the floor of the basin and an eastward dip.

During Middle Cretaceous times a shallow marine transgression, probably from the north, deposited the Osborne Formation disconformably on the preceding Lower Cretaceous. The sea then regressed giving rise to the hiatus which separates the Osborne Formation from the Upper Cretaceous succession. The succeeding Molecap Greensand was also deposited under shallow water conditions, as part of a shallow marine transgression which was initially restricted to an embayment. This bordered the Darling Fault where subsidence was greatest. The Molecap Greensand was succeeded conformably by the Gingin Chalk. By late Santonian—early Campanian times the marine influence regressed westward, depositing the Lancelin Beds in the Guilderton—Lancelin area.

Minor movements along the Darling Fault at the end of the Tertiary (McWhae and others, 1958) caused the development of slippage faults above existing fractures in the Lower Mesozoic sediments. Rotation of a block about 8 miles wide abutting the Darling Fault zone imposed a gentle eastward dip on the Upper Cretaceous succession (Low, 1964), and the coastal belt was downthrown to the west as much as 2,000 feet by faults, trending north-south, and situated about 9 miles inland.

Subsequently the whole area was eroded and is marked by the Quaternary unconformity. Pleistocene eolianite and dune sands were deposited over the erosion surface as far inland as 14 miles.

HYDROLOGY

AQUIFER SYSTEMS

Aquifers of Upper Jurassic, Lower Cretaceous, Upper Cretaceous, and Quaternary age were intersected in the drilling.

Yarragadee Formation Unit I

An Upper Jurassic aquifer similar to the Claremont Sandstone was the main drilling target. A confined aquifer of this age, consisting of coarse feldspathic sandstone interbedded with thick claystone, was encountered only in Bore 3 but is considered younger than the Claremont Sandstone.

This aquifer was tested at a depth of 1,700 feet where a static water level of 89 feet above sea level was recorded. The water salinity was 1,320 ppm TDS. Gamma ray and electric logs of the bore show strata containing low salinity water occurring at depths of 1,900 feet and 2,100 feet. The latter horizon is a clean sandstone about 400 feet thick with a possible water salinity of 500 ppm TDS, and apparently having no hydraulic connection with the more saline water above.

The origin of this water and its direction of movement are not apparent. In other areas also, some bores have better quality deep waters than their shallower aquifers contain, and more work will be needed to find the reason. It is just possible that water from the Moore River and Gingin Brook is seeping down the fault zone west of Bore 3, but one would expect the shallower aquifers to benefit even more from such a source, as they should be at least equally permeable.

Yarragadee Formation Unit II

Unit II is an extensively developed confined aquifer having a maximum thickness of 2,200 feet in Bores 2 and 6. It consists of grey, fine to coarse, feldspathic sandstone with interbedded claystone and siltstone. East of Bore 2 a decrease in permeability of the aquifer is the result of an appreciable increase in the silt content as is evident in Bores 1 and 5.

This aquifer is separated from the Upper Jurassic aquifer in Bore 2 by a thick claystone section and in Bore 3 by thin shaly beds. Correlation of the aquifer between these bores is complicated by a strong easterly dip and by impersistence of strata which causes considerable horizontal and vertical permeability variations. The different beds within the aquifer are, however, well defined and are considered to form one hydraulically interconnected system.

In Bores 2 and 3 static water levels of 161 feet and 130 feet above sea level were recorded from sands at 870 feet and 240 feet respectively, which are roughly the same aquifer horizon. The hydraulic gradient between the two bores falls gently to the west at 4 feet per mile (Plate No. 11). The pressure water from the 240 feet level in Bore 3 has a hydrostatic head of 27 feet above ground level and an estimated yield of 40,000 gallons per hour.

The hydraulic gradient of 4 feet per mile is maintained at least as far east as Bore 1 where a static water level of 320 feet above sea level was recorded.

Between Bores 3 and 6 two inferred step faults have downthrown the unit by at least 2,000 feet to the west. The form of the piezometric surface over the fault zone is uncertain, but it appears to increase appreciably in gradient to 18 feet per mile since a static head of 35 feet above sea level was recorded in Bore 6.

Recharge probably takes place along the Darling Fault zone and by seepage from Gingin Brook percolating down through the Quaternary limestones. Effective recharge from Gingin Brook is suggested by the chemical similarity between water in the brook and samples from Bores 3 and 6. Intake may also occur along the north-trending fault zone between these bores.

It must be noted however, that some fault zones in the northern Perth Basin, particularly at Arrino, are thought to act as effective barriers to water movement across or down the fracture lines. Milbourne (pers. comm.) reports that these zones are kaolinitic which may explain their impervious nature. Kaolinite was not noted from any of the Gingin Brook bores.

Without any test pumping of the Lower Cretaceous and Upper Jurassic aquifers it is difficult to comment on the quantity of stored water available, but it is probably quite large since sandstone sections are mainly thick and inter-connected.

Upper Cretaceous

The Molecap Greensand forms the only aquifer of this age encountered in the drilling. Lithologically this aquifer consists of unconsolidated glauconitic sandstone and siltstone. It is separated from the Lower Cretaceous aquifer system by the Osborne Formation in Bore 1 and by an unconformity at the type section at Molecap Hill near Gingin. The Osborne Formation is a most effective aquiclude and water held up by it issues as springs in the dissected Ginginup area forming the source of Gingin Brook. Recharge is direct from rainfall and along the Darling Fault zone where many small streams apparently disappear into the ground.

Quaternary

Details of the shallow unconfined aquifer located in all bores west of No. 5 are given in Table 3. The aquifer consists of unconsolidated superficial sand, eolinite, and Coastal Limestone.

Table 3

QUATERNARY AQUIFER

Bore No.	2	3*	6	4	Guilderton
	ft.	ft.	ft.	ft.	ft.
R.L. of bore head	191.5	103.2	69.2	32.5	30.0
Depth to water table	20	40	60	18	30.0
Thickness of aquifer....	150	100	80	125	>114
R.L. of water table....	170	130	9	24	0

* Bore 3 was sited alongside Gingin Brook and pressure water with a hydrostatic head of 27 feet above ground level was encountered at 40 feet.

The Quaternary aquifer extends south to the Bullsbrook and Gnangara areas where it forms an extensive groundwater province. A contour map and the water table profile suggests that the main intake for the aquifer occurs in the region between Bullsbrook and Gingin, direct recharge being effected by precipitation. A large quantity of water would be available from this aquifer.

The groundwater is moving westward under a gentle gradient, movement probably being controlled by the subsurface erosion slope on the Mesozoic rocks.

QUALITY OF THE UNDERGROUND WATER

The chemical nature of the underground water is indicated by standard chemical analyses and these are given in Table 4. Schoeller's (1959)

Table 4

WATER ANALYSES BY GOVERNMENT CHEMICAL LABORATORIES—GINGIN BROOK BORES

Bore		1	Gingin Town Bore	5A		5	2	3				6			4		
Aquifer Section tested Depth in feet		380–400	380–400	20–200	Gingin Brook	50–100	914–955	30–100	240–260	1400–1500	1657–1727	1110–1170	1820–1910	2270–2400	* 35–45	600	1734–1758
Specific Conductivity 20°C (Micromhos)		460	290	1530	420	1290	1810	1110	1200	2050	1890	1170	1530	2510	2240	750	1650
pH		7.8	6.6	5.6	6.7	8.1	9.2	7.7	6.9	7.4	7.4	6.9	7.4	8.0	8.4	6.9	7.8
Mineral matter ppm	Calcium, Ca	22	2	14	4	52	49	59	18	38	46	21	28	11	36	11	34
	Magnesium, Mg	7	4	25	8	19	1	21	21	22	30	19	19	15	13	11	21
	Sodium, Na	74	49	270	76	235	354	161	210	387	311	198	271	564	479	166	295
	Potassium, K	5	9	11	2	7	18	6	11	32	36	13	19	23	9	11	24
	Bicarbonate, HCO_3	128	15	30	27	366	104	247	92	256	238	107	149	366	375	161	232
	Carbonate, CO_3	....	....	....	....	....	39	....	....	....	....	....	....	....	8	....	....
	Sulphate, SO_4	24	12	37	13	64	53	5	34	90	63	30	61	149	138	29	77
	Chloride, Cl	85	81	480	123	255	495	272	348	541	496	324	408	631	519	203	407
	Nitrate, NO_3	....	< 1	1	1	1	< 1	....	....	....	1	1	1	1	....	....	1
	Iron, Fe	0.2	0.9	<0.1	0.5	6	<0.1	0.1	0.5	<0.1	....	<0.1	0.1	0.8	<0.1	0.2	0.2
Total ppm	By conductivity	320	200	1070	290	900	1270	780	850	1440	1320	820	880	1760	1570	520	1160
	By evaporation	310	170	890	260	850	1070	690	730	1220	1100	690	1070	1610	1430	500	1000
Hardness	Total	84	21	138	43	208	126	233	131	186	238	130	148	89	143	73	171
	Bicarbonate	84	12	....	....	....	....	203	76	186	....	....	....	....	143	....	....
	Non-carbonate	....	9	....	....	....	....	30	55	....	....	....	....	....	....	....	....
	Calcium	55	5	....	....	....	....	147	45	95	....	....	....	....	90	....	....
	Magnesium	29	16	....	....	....	....	86	86	91	....	....	....	....	53	....	....

method of plotting ions as milli-equivalents on semi-logarithmic graph paper has been used to compare chemical characteristics of water from various aquifers. Most samples selected for analysis were considered to be uncontaminated by drilling fluids.

Yarragadee Formation aquifers

The *Unit I* aquifer was tested over the interval 1,657 to 1,727 feet in Bore 3. The quality of the water is fair, being 1,320 ppm TDS and is chemically similar, but slightly less saline, than the water from the overlying lower Cretaceous aquifer. The water is also slightly acidic, the pH being 6.9.

The bore was not tested below 1,727 feet but the resistivity log shows domestic quality water of about 500 ppm TDS occurring at a depth of 2,100 feet.

Water from the *Unit II* aquifer shows considerable variation in chemical character and a gradual increase in the concentration of dissolved solids from east to west.

In Bores 1 and 5 domestic quality water of between 320 and 430 ppm TDS occurs in clean sand interspersed with minor clay and silt above 400 feet. There is a marked deterioration in quality with depth, resulting from a downward decrease in permeability. The Gingin town bore located near Gingin Brook, ¾ mile east of Bore 5, has similar aquifer characteristics, but is fresher with 200 ppm TDS. Bore 5A sunk alongside the brook a few hundred yards south of Bore 5 encountered artesian water with a hydrostatic head of 10 feet above ground level, at only 40 feet depth. The water here contains 1,070 ppm TDS with a pH of 5·6. The acidity is attributed to a high feldspar content in the sediment forming the aquifer, but appears to be a localised feature.

The water in all these bores is chemically comparable to Gingin Brook indicating it is the main source of recharge.

In Bores 2 and 3 the near surface water is also controlled by Gingin Brook. In Bore 2 water of 380 ppm TDS was intersected at 360 feet depth. Unfortunately the sample was contaminated with drilling fluid which prevents accurate chemical comparisons. Below 400 feet the water deteriorates to between 1,090 and 1,200 ppm TDS, remaining at this latter value to a depth of 2,400 feet.

In Bore 3 the water is artesian at 240 feet and has a salinity of 850 ppm TDS. There is a considerable increase in the concentration of dissolved solids below 400 feet reaching a maximum of 1,440 ppm TDS at 1,400 feet.

In this area the salinity variations within the aquifer are large enough to affect the suitability of the waters for specific purposes. Generally domestic quality water is restricted to the near surface horizons. This however, may be due to the close proximity of Gingin Brook but is probably common to the whole area owing to leakage from the Quaternary aquifer. The water below 500 feet does not reach the standard for domestic use, but is of excellent stock quality and could be used to irrigate the more salt-tolerant fodder crops.

In Bore 4 an artesian flow of small yield was encountered at a depth of 600 feet. The water salinity was 520 ppm TDS with a pH of 6·9. The salinity of the confined water gradually increases with depth to 1,050 ppm TDS at 1,750 feet.

Domestic quality water occurs throughout Bore 6, the average total salt content being about 800 ppm TDS. The best water is at 515 to 665 feet where it is 680 ppm TDS and slightly acidic. The water at 1,100 feet is 820 ppm TDS and is chemically comparable to the water at 240 feet in Bore 3. Below 1,170 feet the water becomes mildly alkaline.

Water in the Yarragadee Formation aquifers in the Gingin Brook area is chemically dissimilar to that sampled in the Bullsbrook bores where the water is generally fresher (Whincup, 1966). Here recharge is mainly from the Darling Fault zone with water moving gradually westward. Near Gingin, recharge is associated with Gingin Brook and accordingly the water may not be representative of the underground water elsewhere in the basin. Structurally the Bullsbrook area is quite different from the Gingin area but the presence of thick aquifers of the same age is recognised. A hydraulic connection between the two areas cannot be established from available data.

Upper Cretaceous aquifer

Water in the Molecap Greensand is of domestic quality and many shallow wells east of Gingin, penetrate this aquifer. Landholders report that the water is very soft, and this is probably due to the glauconitic nature of the rocks.

Quaternary aquifer

Potable water is found in the Quaternary aquifer over the whole area west of Gingin. The average total salt content is about 700 ppm TDS often increasing markedly with depth. This is evident in Bore 4 where water salinity increases from 700 to 1,570 ppm TDS within 18 feet. At Guilderton salinities are higher than normal, ranging from 1,380 to 2,200 ppm TDS as a result of sea water contamination.

CONCLUSIONS

The exploratory drilling programme has provided important new stratigraphic and hydrological information in this part of the Perth Basin. The Upper Jurassic—Lower Cretaceous aquifer system known from Mandurah to Bullsbrook has now been seen to extend as far north as Gingin, but it may not be hydraulically connected.

Over the whole drilling area underground water is available from at least four independent superimposed aquifers. The volume of stored water available was not tested but is probably quite large due to the thickness of the sandstones forming the aquifers.

The Upper Jurassic aquifer was penetrated in Bore 3 below 1,600 feet. Domestic quality water is indicated by electric logs as occurring at 2,100 feet but water above this depth is too saline for domestic purposes.

An extensive Lower Cretaceous section was encountered in all bores. Its maximum development is in Bore 2 where it attains a thickness of 2,260 feet. Water of domestic quality is restricted to within 500 feet of the surface in the middle of the drilling area. Below this depth the water is saline but still of excellent stock quality.

In the western segment of the area the Lower Cretaceous aquifer occurs below the thick, impervious Osborne Formation. The water in this aquifer is generally of domestic quality.

The Molecap Greensand of Upper Cretaceous age forms a thin aquifer containing potable water, in the eastern segment of the drilled area.

A shallow, unconfined Quaternary aquifer was penetrated in all bores west of Bore 5. This aquifer generally holds domestic quality water and is seen to be a northern extension of the large groundwater province at Gnangara, just north of Perth.

The water in the Yarragadee Formation aquifers in the Gingin area is not directly comparable with that from the South Perth Formation and Claremont Sandstone known from bores near Bullsbrook and Perth. The underground water in these areas is generally fresher than in the Gingin Brook bores. Structurally the areas are quite different but the presence of thick aquifers of the same age is recognised. A comprehensive drilling programme in the Muchea—Yanchep area would be required to establish hydraulic connection between Gingin and Bullsbrook.

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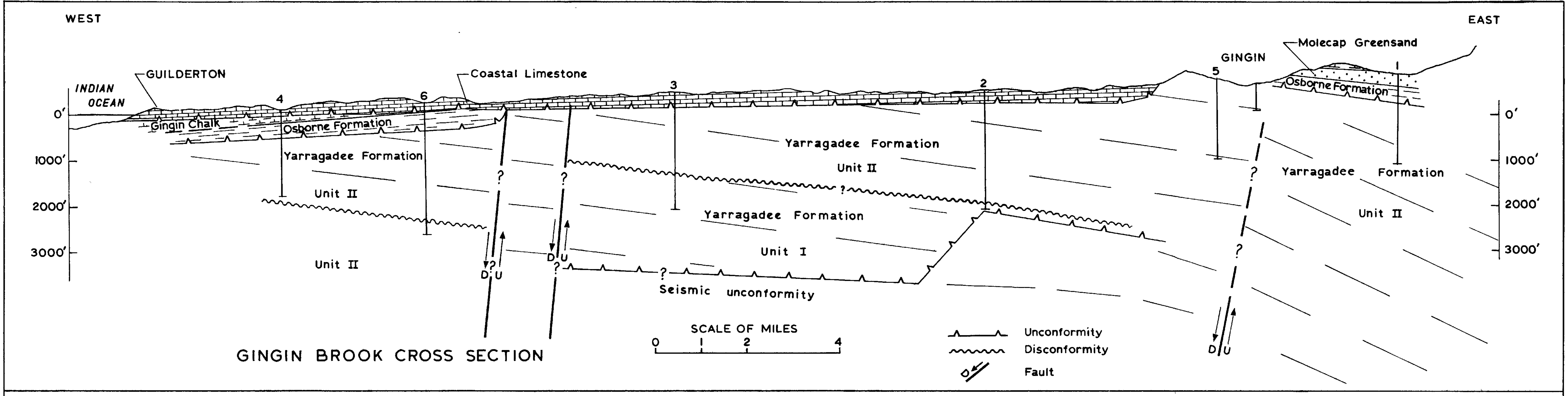
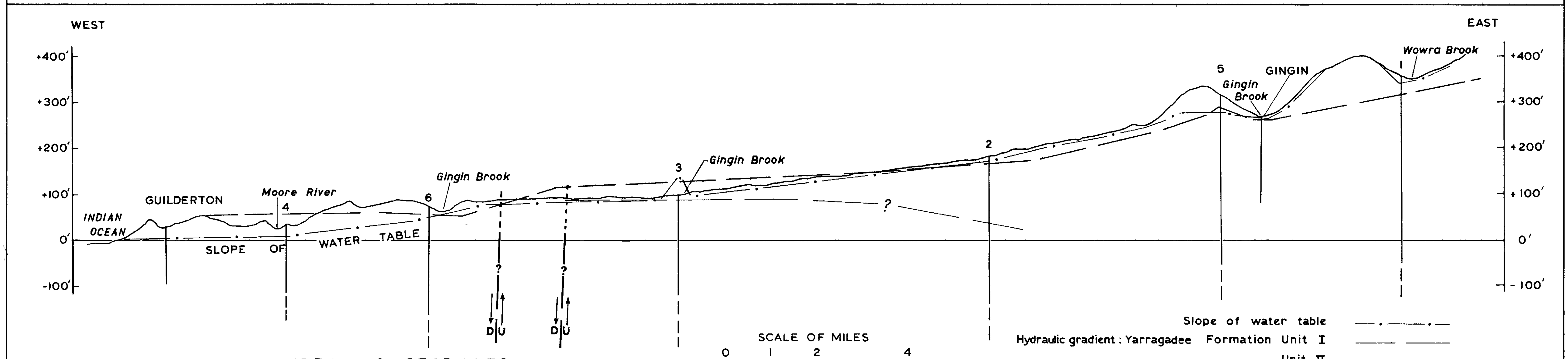
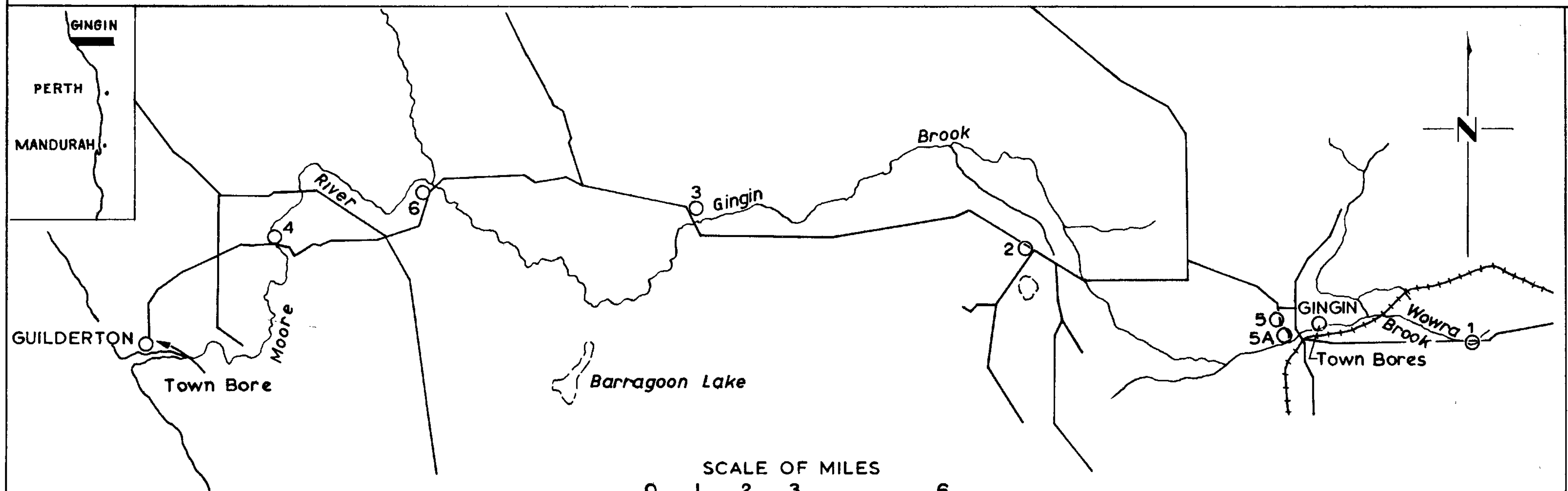


GINGIN BROOK CROSS SECTION



HYDRAULIC GRADIENTS



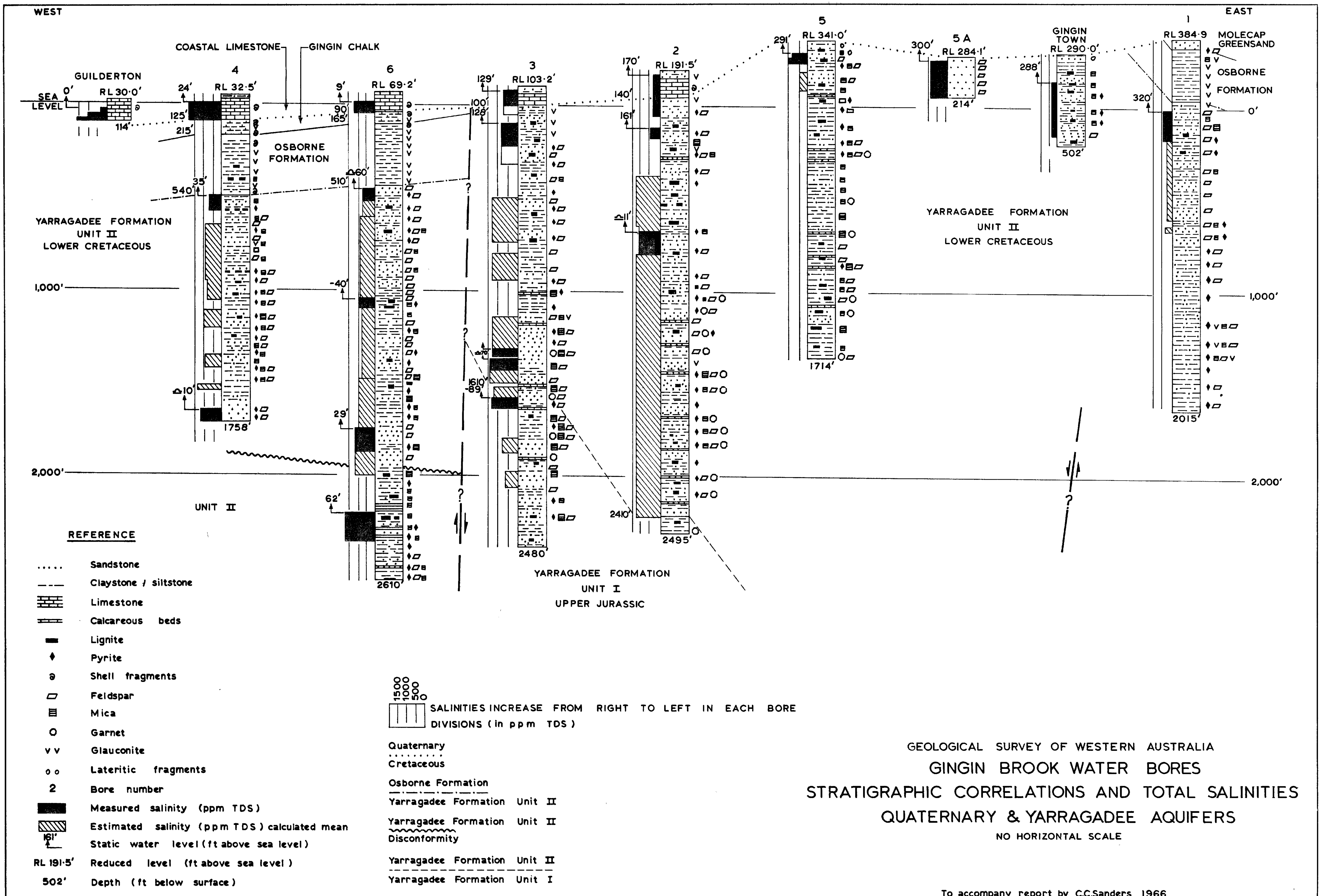
LOCALITY MAP

GEOLOGICAL SURVEY OF WESTERN AUSTRALIA

GINGIN BROOK WATER BORES LOCALITY PLAN AND SECTIONS

To accompany report by C.C.Sanders, 1966

PLATE II



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GEOLOGICAL RECONNAISSANCE AT MACDONALD GORGE DAM SITE, WEST KIMBERLEY

by F. R. Gordon

INTRODUCTION

The Public Works Department scheme for the regulation and development of the rivers of the West Kimberley area includes two possible dams and a diversion structure on the Margaret River, which is the most important tributary of the Fitzroy River system. Its middle reaches, extending through the Louisa Range, the Mueller Range, the Mt. Cummings Plateau, and the King Leopold Range, are largely rock bound. Many good dam sites are available and one of the best is situated in a major topographic constriction at Macdonald Gorge in the King Leopold Range, before the river debouches on to the alluvial flats and flood plains of Fitzroyland.

GEOLOGICAL SETTING

Topography

Macdonald Gorge has long been regarded as an obvious choice for a dam site because the natural barrier of the King Leopold Range is breached by a narrow steep sided rock gorge and there is a wide flat storage area immediately upstream, known as the Mt. Ball Basin.

On the left bank the walls of the gorge rise at an average slope of about 52° to 300 feet above the alluvium in the river bed. The right bank on the survey line is steeper, with an average slope of 60°, and rises immediately to about 250 feet above the river bed. It is noteworthy that on both cliffs there is a 40 foot high section of vertical or overhanging wall at the foot of the slope. Although water jetting has been done in the river bed by P.W.D. no results are available, and in view of the difficulties encountered at the Ord site, it is recommended that the bottom should be redetermined with auger drillholes.

The cliff on the north side of the gorge has been breached by a sawcut gorge (herein named Ratio Gully) up to 250 feet deep, that continues for some miles to the north in the centre of the King Leopold Range. A similar feature, but not so profound, divides the range on the southern side of the gorge.

The Mt. Ball Basin opens out immediately upstream of the King Leopold Range. It is roughly oval in shape with the river forming the shorter axis. To the east, the basin ends where subdued foot-hills appear on each side of the river. Further to the east the river runs in a gorge through another major quartzite escarpment which forms the No. 2 dam site, 4½ miles upstream from the No. 1 site.

Subdued outcrops of weathered and eroded igneous rocks of the Lamboo Complex appear through the broad composite valley plain of the Margaret and Leopold Rivers to the west of the King Leopold Range. The westerly flowing Margaret River joins the Leopold River 4 miles west of the dam site, and the combined flow is known as the Margaret River, and continues in a southwesterly direction.

About 3 miles to the north of the gorge, there is another natural break through the King Leopold Range at Jenney's Glen. This is a possible emergency spillway site.

Rock types

The main rock types and their distribution are shown in Plate 14. The Mt. Ramsay 1:250,000 Sheet area has recently been mapped by a joint party from the Bureau of Mineral Resources and the W.A. Geological Survey (Roberts and others, 1965) and this work has provided a geological setting for the project, and given a nomenclature to the rock types. Details of the stratigraphy of the area are shown on the accompanying map.

The *alluvium* consists of mud, silt, sand, and gravel. In the creek beds and over the extensive flood plains of the Margaret River, the alluvium is generally sandy or silty. In the river bed itself, particularly in the vicinity of Macdonald Gorge, layers of mud are common and there are lenses of decaying vegetation. Probably most of the bed alluvium is renewed each year and the " permanent " pools that form in the dry season vary in size but little in position, indicating some control from bedrock structure.

The *residual soils* which reflect the variable nature of the underlying bedrock, consist of sand, soil, black soil, and some alluvium, and the major part of this material has been developed more or less *in situ*.

The *Burramundi Conglomerate* consists of rounded to subangular boulders, cobbles, and pebbles of various Precambrian rocks especially quartzite set in a matrix of sand, often ferruginized, but in many exposures the larger stones are practically touching. The formation was originally named by Guppy and others (1958) and has been included by Playford and Lowry (1966) in ' Undifferentiated Conglomerates ' of uncertain Devonian—Permian age.

The *Hart Dolerite* is exposed adjacent to the King Leopold Range and in the Mt. Ball Basin where it forms low-lying partly soil covered boulder strewn areas.

The formation consists of massive, greenish black, medium to coarse-grained dolerite, usually well jointed in outcrop. The dolerite occurs as sills intrusive into the O'Donnell Formation and the Luman Siltstone (Roberts and others, 1965).

Carson Volcanics. This formation consists of green black, fine to coarse-grained, sometimes amygdaloidal basalt, which is interbedded with thin beds of pink to mauve current-bedded felds-pathic sandstone. The volcanics are not resistant to weathering and generally occupy low ground between ridges and escarpments of King Leopold Sandstone and Warton Sandstone (Roberts and others, 1965). Stratigraphically they lie conformably between these two formations.

The *King Leopold Sandstone* consists of white to pink, blocky to massive, medium to coarse-grained quartz sandstone. It is commonly current-bedded, with frequent pebble bands and ripple marks. There are minor occurrences of feldspathic sandstone. The rock is particularly resistant to weathering and forms strong steep sided ridges and cuestas.

Valentine Siltstone. This formation is normally poorly exposed and it is usually seen in valleys. The rock consists of grey to brown fissile shale and siltstone. Narrow zones of this formation crop out north of the Macdonald Gorge.

O'Donnell Formation. This formation consists of olive and brown shale, siltstone, and silty shale in the upper part, and medium to coarse-grained siliceous quartz sandstone at the base. The upper members are poorly resistant to weathering, and rounded, maroon coloured hills develop. The basal arenite is resistant to weathering and forms strong ridges.

Violet Valley Granite. This is a member of the Lamboo Complex and consists of equigranular, medium to coarse-grained biotite granite. It characteristically occurs in large exfoliating outcrops of low relief.

The *Bow River Granite* is a member of the Lamboo Complex, and consists of porphyritic and coarse-grained granites, with minor occurrences of granodiorite and aplite. The granites have little topographic expression in their exposure in the valley of the Leopold River, west of the King Leopold Range.

The *Olympio Formation* is a member of the Halls Creek Group, and consists of grey to brown thick-bedded massive quartz greywacke and feldspathic greywacke intercalated with thin-bedded siltstone, fissile shale, and carbonaceous siltstone. The topographic expression varies considerably between rounded steep hills and low rises with poor outcrop.

Faulting

The dam site is situated in a zone of severe faulting that extends from Mount Huxley in the south, to Mount Winifred in the north. The zone is about 10 miles wide, and the larger faults strike north or east of north, while another strong set has an easterly trend. North of the Margaret River there has been minor faulting with a north-easterly trend.

The various faults in the vicinity of the dam site as interpreted from air photos are shown in Plate 14. It must be emphasised that detailed mapping is needed to define the number and location of faults that trend northerly along the strike of the King Leopold Sandstone. There are several possibilities that fit the geomorphological pattern shown by photo interpretation.

The only fault apparent on a regional scale that has a direct influence on the foundation area of the dam is found in the central portion of the gorge in the King Leopold Range, striking at right angles to the Margaret River and dipping at 70° to 80° to the west. This fault, known as the Ratio Gully Fault, crosses the proposed centre line at an acute angle of about 35°, close to the foot of the cliff on the southern abutment. In the gorge there are at least 5 other visible faults parallel to the main one, and usually marginal to the major folded structures. Breccia zones are associated with some of them.

In the gorge area only one fault was noted parallel to the flow of the river. This was seen on the downstream end of the gorge on the left hand bank, where a block about 100 feet wide is separated from the main bulk of the King Leopold Range.

Folding

In the strongly faulted area of the King Leopold Range in Macdonald Gorge, large drag folds are developed on a spectacular scale.

Panoramic views of the north and south walls of the gorge in the vicinity of the survey line have been included to indicate the variety and complexity of the folding (Plate 12). Detailed mapping will be needed to clarify the problems that will have to be solved, including the best location of the centre line, and the amount of diamond drilling that will be needed to gauge the permeability of the foundation area. As a consequence of the folding and faulting some large gapes have opened up, and the extent and size of these openings are probably unique.

SITE APPRAISAL

As already noted the King Leopold Range in the vicinity of Macdonald Gorge has been divided along its length by the Ratio Gully Fault. The resulting blocks on either bank are dissimilar. The downstream block on the south abutment is not topographically as prominent as the upstream block, and large-scale block gliding and deep weathering mean that this downstream block is not desirable as a foundation area.

On the northern abutment, the downstream block is topographically the stronger, while the upstream block is subdued. Although all the major faulting and folding has been confined to the downstream block, the upstream block is not a suitable foundation area for a dam because of lack of relief and breaching of the reservoir rim to the north.

This means that the preferred centre line will cross the Ratio Gully Fault at an acute angle. It also means that many of the folded structures, which appear to trend parallel to the fault, will not cross the centre line. Folded quartzite beds will occur in the foundation area of the dam, and in view of the tightness of the folding and the distance apart of the walls of the gorge (approximately 360 feet), correlations from wall to wall will be almost impossible to make. Diamond drilling of the river bed will need to be on an intensive scale but it is doubtful if the full pattern will be revealed until the foundation area is excavated. The structure of the rock in the river bed will have a dominating influence on the topography of the bedrock, and some highly irregular patterns may be expected, requiring the excavation of deep fissures and the large scale use of dental concrete. Filling of the gapes opened in the folds to prevent consolidation of the rock under load and to seal off leakage paths, will need a programme of curtain and blanket grouting.

The vertical walls in the lower part of the gorge almost certainly extend below the alluvium in the river bed. This situation is ideal for the construction of a concrete dam, but imposes certain difficulties on the construction of the clay core of a rockfill dam.

The topographic saddle at Jenney's Glen was not visited. From air-photo interpretation it appears that erosion after faulting oblique to the range has exposed a tongue of Hart Dolerite through the King Leopold Range.

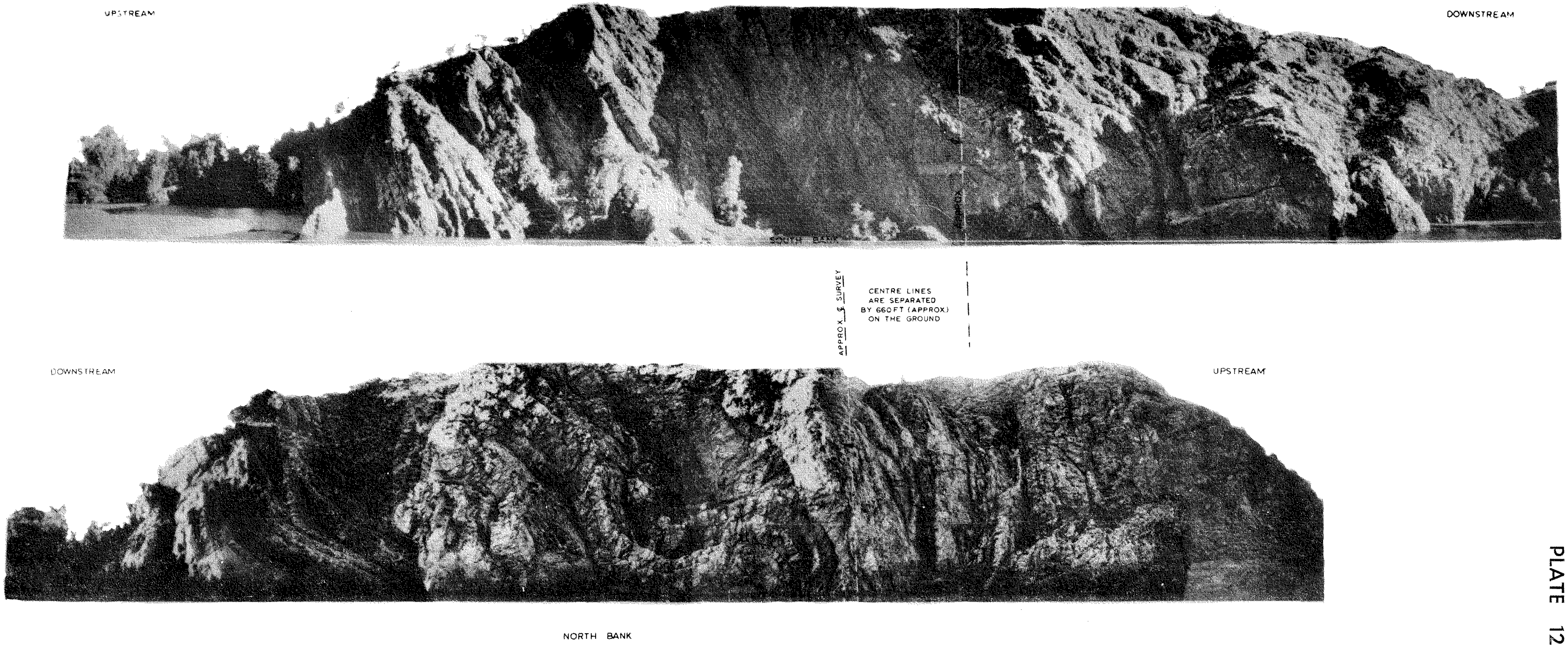
CONSTRUCTION MATERIALS

All the rock necessary to build a rock fill dam is immediately available on the site. However material for the clay core will involve considerable proving and testing. A possible source is on the south side of the Mt. Ball Basin where the following sequence is seen in the rapidly eroding creek beds:

- 0– 4 feet, recent silt and soil
- 4–14 feet, reddish loam
- 14–24 feet, horizontally bedded gravel
- 24–30 feet, calcareous cemented gravel.

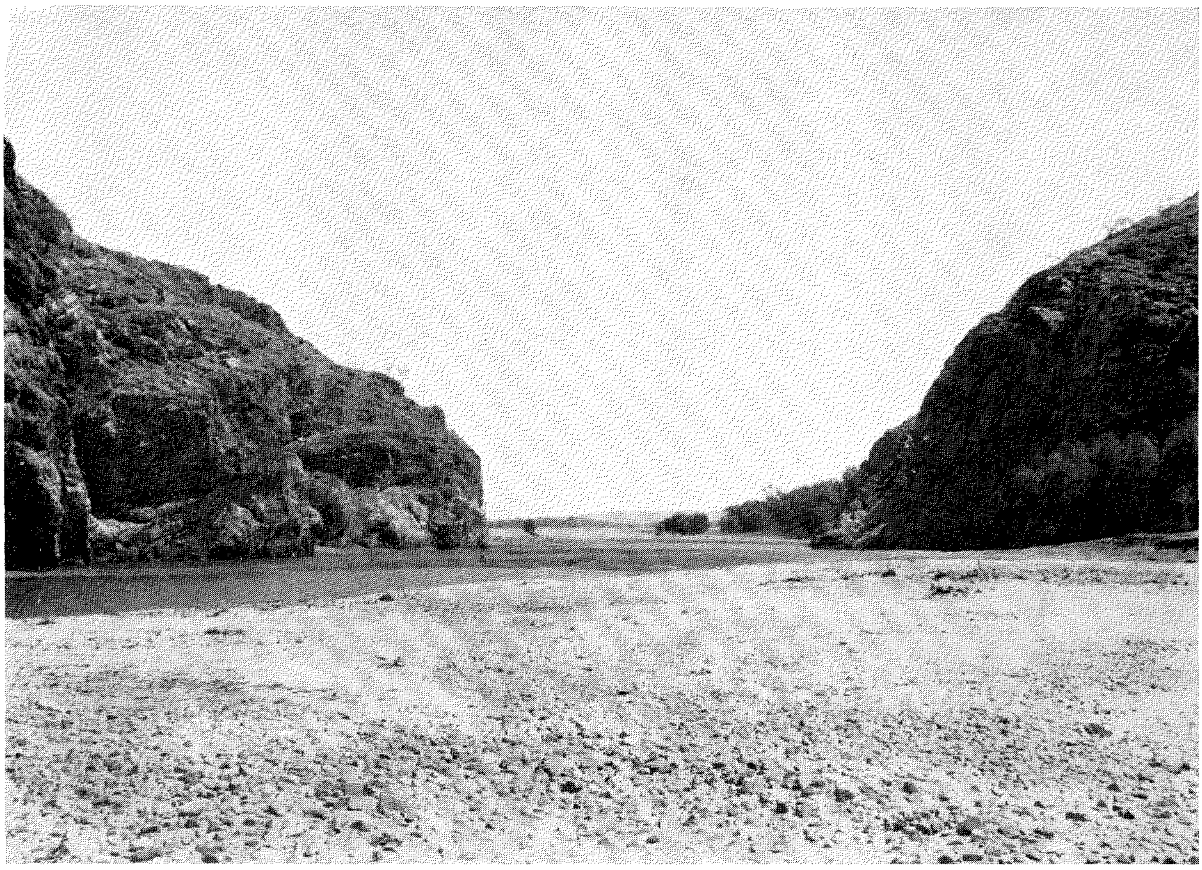
The 10 foot thick, old, reddish loamy soil is a possible clay core material.

The gravels of the Margaret River have a considerable component of chalcedony, derived by alteration of the bedded limestone of the Lawford Beds. If the agate and chalcedony

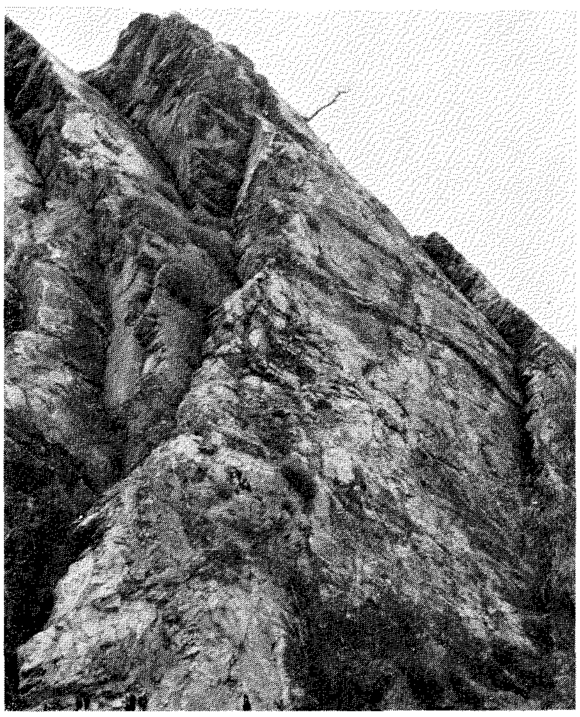


MACDONALD GORGE DAM SITE—PANORAMIC VIEWS OF NORTH AND SOUTH BANKS (F1148)

PLATE 13

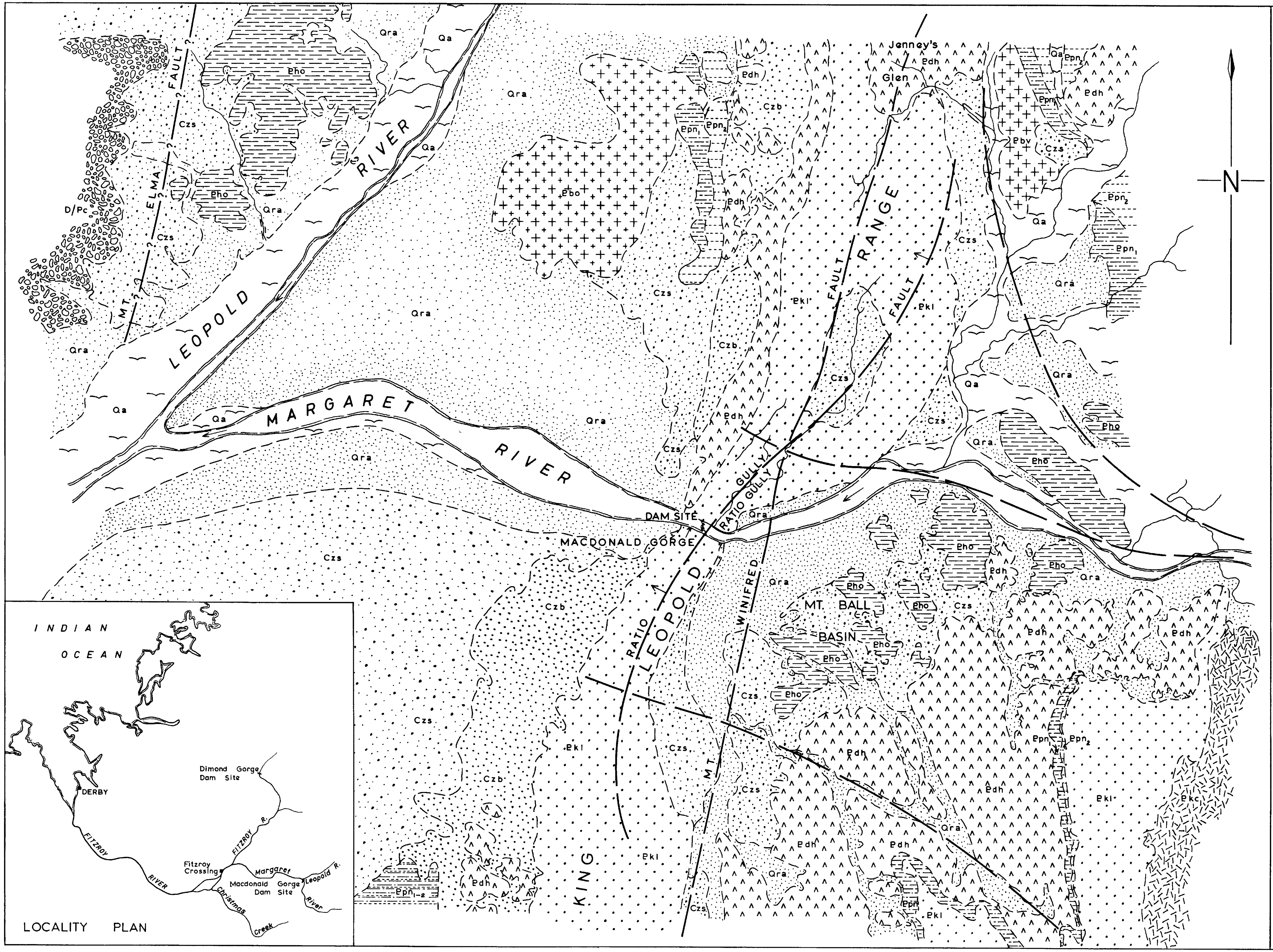


A—Macdonald Gorge looking west. Dam centre line crosses gorge in immediate foreground. Ratio Gully Fault crosses from lower right to near tree filled embayment, left centre ; F 1142.



B—Folding in King Leopold Sandstone immediately upstream of centre line on right abutment ; F 1146.

C—Folding showing well developed gapes immediately upstream of centre line, left abutment ; F 1147.



REFERENCE

CAINOZOIC	QUATERNARY		Qa	Alluvium
			Qra	Sand
	UNDIFFERENTIATED		Czb	Black soil
			Czs	Residual soil, sand
PALAEOZOIC	PERMIAN ? DEVONIAN	BURRAMUNDI CONGLOMERATE	D/Pc	Boulder, cobble and pebble conglomerate
PROTEROZOIC	UPPER PROTEROZOIC	HART DOLERITE	Ꝑdh	Green black, medium to coarse-grained dolerite
	MIDDLE PROTEROZOIC	CARSON VOLCANICS	Ꝑkc	Green black basalt, amygdaloidal basalt, minor sandstone and siltstone
		KING LEOPOLD SANDSTONE	Ꝑkl	White, medium to coarse-grained quartz sandstone, pebble conglomerate
		VALENTINE SILTSTONE	Ꝑpn₁	Purple grey and brown, fissile, fully laminated shale and siltstone
		O'DONNELL FORMATION	Ꝑpn₂	Olive green to fawn micaceous silty shale, coarse quartz sandstone base
	LOWER PROTEROZOIC (UNDIFFERENTIATED)	LAMBOO COMPLEX: VIOLET VALLEY GRANITE	Ꝑbv	Equigranular, medium to coarse-grained tonalite
		LAMBOO COMPLEX: BOW RIVER GRANITE	Ꝑbo	Porphyritic granite, coarse-grained granite, granodiorite, aplite
		HALLS CREEK GROUP: OLYMPIO FORMATION	Ꝑho	Quartz greywacke, feldspathic greywacke, siltstone, shale, carbonaceous siltstone

SYMBOLS

- Geological boundary position approximate
- Fault
- Anticline
- Syncline
- 15 Dip and strike of strata
- Trial line of dam site

SCALE OF MILES

3/4 1/2 1/4 0 1 2

GEOLOGICAL SURVEY OF WESTERN AUSTRALIA

MACDONALD GORGE DAM SITE
MARGARET RIVER
GEOLOGICAL PLAN

To accompany report by F.R.Gordon

9456

laden gravels of the Ord River are not considered deleterious for use in concrete, it would be presumptuous to condemn the Margaret River gravels.

Dimension stone is readily obtainable from the massive beds of the King Leopold Sandstone.

INVESTIGATION PROGRAMME

An extensive investigation programme will be necessary to bring the Macdonald Gorge dam site from the reconnaissance stage through the feasibility stage to the commencement of design.

(1) Survey. It is recommended that the gorge area be surveyed and mapped by phototheodolite.

(2) Geological mapping is intimately bound up with the mapping of the gorge walls by phototheodolite. A scale of 50 feet to the inch is suggested for all work in the vicinity of the dam site.

(3) Probing by Gemco drill, at 10 foot centres, of the possible foundation area in the river bed, is considered necessary.

(4) On the results of the geological mapping and the bedrock profile as revealed by drilling, a diamond drilling programme can be designed. It will necessarily be extensive.

(5) Sources of construction material should be confirmed or investigated.

On the basis of this programme the type of dam may be selected and the final centre line established.

CONCLUSIONS

1. Although the dam site at Macdonald Gorge has several of the attributes of an excellent location for a dam, the geological structure of the foundation rocks is complex because of intensive faulting and drag folding.

2. The dam site on the Margaret River may be compared with the Dimond Gorge dam site on the Fitzroy River which has also been investigated in the reconnaissance stage. Because of its simpler geological structure, the Dimond Gorge dam would be a much more economic proposition to investigate and construct.

3. An extensive programme of investigation has been outlined for the Macdonald Gorge site. the 'unknowns' are far too numerous and weighty to allow a firm choice of type of dam or centre line at this stage.

4. Further investigation of the possible spillway area at Jenney's Glen will be necessary.

5. It is recommended that detailed surveying of the gorge should be done by phototheodolite. Other similar sites such as Dimond Gorge could be included in this programme.

6. The dam site has obvious merit in the small cross section of the gorge that will need to be dammed. There is a reasonably large upstream storage basin, and the site itself is geographically the closest of the main dam sites to the proposed irrigation areas.

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REVIEW OF A QUARRYING OPERATION AT MERREDIN, STANDARD GAUGE RAIL PROJECT

by F. R. Gordon

INTRODUCTION

The Standard Gauge Railway between Northam and Kalgoorlie traverses part of the great inland plateau. The rock series with the exception of some laterite is probably of Precambrian age, and represents highly folded ancient sediments, pyroclastics, lava flows, and basic intrusives, which have been invaded by granitic magmas. The folded remnants of the intruded rocks form a slight topographic relief, generally as north-northwesterly directed ridges. Most of these low rounded ridges are of greenstone, while the shrub covered country and sandplain overlie areas of granite gneiss. The most conspicuous topographic features of the area are numerous large bare granite masses known as 'rocks' and are regarded as bosses of granite intruded into the gneiss complex.

Between Northam and Southern Cross these rocks are practically the only source of ballast (Gordon, 1964).

BALLAST REQUIREMENTS

The physical requirements for stone used for ballast have been established through empirical observations, and little is known concerning the exact relationship of the specification tests employed and conditions in the rail bed. The desired properties have been detailed in connection with previous contract sections (Gordon, 1964, 1965). In summary the rock

1. must be particularly resistant to impact
2. must have a high abrasion resistance
3. must not break down under traffic, but must not be too strong for efficient crushing
4. must have good mechanical interlock
5. must not deteriorate rapidly because of weathering. The basic properties of a rock that influence its usefulness include resistance to weathering, hardness, toughness, cleavage, density, composition, porosity, and structure.

The shape and size of the ballast pieces as produced from the treatment plant are also important. The usual tests to determine the suitability of a stone for ballast are those for soundness, resistance to abrasion, specific gravity, particle shape and fractures, soft particles, and gradation. However, a specification for ballast usually only specifies a grading and a maximum loss in a Los Angeles abrasion test, and beyond a general correlation between low L.A. loss and sound performance as a ballast, little is known of the ultimate performance of rock closely specified by L.A. results.

A particular source of ballast must be further evaluated in terms of its potential as a working quarry.

1. The deposit should be close, say within 2 miles, of existing or proposed railway lines.

2. The extent and depth must be assessed in order to give a probable yield, which must be considerably more than the ballast quantity.

3. The physical properties of the rock must be evaluated with regard to wastage, excessive fines, ease of breakage by explosives, and by crushing plant.

4. There must be easy access and the possibility of a good plant layout.

SITE SELECTION AND TESTING

The contractors proposed to work only from an abandoned Australian Blue Metals—Railway quarry 1½ miles south of the town of Merredin (Plate 15). This quarry had not been considered in the reconnaissance survey, and the consultants to the Western Australian Government Railways, Maunsell & Partners, were not convinced that it would supply ballast capable of meeting the specification. Further tests were initiated jointly by the contractor and the consultants with the aid of the Mines Department. The rock from the abandoned quarry was compared geologically with a much finer-grained granite, theoretically preferable, that came from an outcrop near the Merredin Rifle Range. The latter had been favourably commented upon in the reconnaissance report. Both field and petrological examinations showed that granulation of large quartz grains in the coarse-grained granite was responsible for excessive breakage in the quarry and in L.A. tests. In the finer-grained rock the breakage was partially controlled by the feldspar component which was in a matrix and not concentrated in large matchbox-shaped laths.

Further surveys were made of the abandoned quarry and of the existing A.B.M. quarry, 2½ miles north of Merredin. In both places the quarry floors were covered with a thick mantle of sand, and there were large piles of reject fines close to the crusher site. The rock in the abandoned quarry was coarser in grain size than in the working quarry. Samples from old stock piles and from current production runs showed L.A. losses of 43 to 54. Both quarries were at the point of maximum face height working into the hill, and thus further work in both would result in an increase in the proportion of weathered rock from sheeted areas near the surface. In the abandoned quarry from 1/3rd to 1/5th of the face consisted of weathered rock. Undoubtedly this was the reason for the Railway Commission relinquishing the lease. Several piles of oversize rocks in the quarry were sampled and tested by the contractor giving an L.A. loss of 22, but this low figure was not considered representative of the quarry material.

These considerations favoured a shift of emphasis to the Rifle Range site, 2 miles east of Merredin, and ½ mile north of the Standard Gauge Railway line. The outcrop, oval in shape, is elongated in a northeasterly direction; the major axis is 2,600 yards and the minor axis 600 yards. The rock is a fine to medium-grained granite, with coarse pegmatitic and porphyritic segregations, with lenses of fine-grained basic rock. No joint sets are apparent apart from sheet joints which are well developed. The geology of the outcrop is obscured by surface weathering and a thin skin of limonite weathering. There is a certain amount of loose rock from the remnants of sheet jointed seams and to the west the outcrop is obscured by high-level sand. Some small depressions on the rock surface are occupied by clay and sand, and these are often the result of deeper weathering because of the incidence of joints or of a more schistose rock type.

In order to further investigate the site, and at the request of the consultants, five diamond drillholes were put down by the Mines Department at sites jointly agreed upon by the consultants, the contractor, and the Mines Department. No site supervision of the drilling was exercised by the Geological Survey, but the core on arrival in Perth were logged geologically and were photographed. The following subdivisions were employed:

1. granite, fine-grained, and aplite
2. granite, medium-grained
3. granite, coarse-grained
4. pegmatite
5. basic lenses.

It was found in practice that there was considerable overlap between the divisions, in particular, medium and coarse-grained types often co-existed in alternating bands up to 1 inch thick.

The outstanding feature of the physical condition of the cores was the almost complete lack of joints other than sheet joints parallel to the ground surface. Chemical weathering was governed by the sheet joints and in general the top 5 feet of core was stained with limonite. Over this depth, the sheet joints had an incidence of one every foot, whereas for the remainder of the hole the incidence became progressively less. The average distance between sheet joints for the complete hole was 3 feet 6 inches. The length of each stick of core was recorded on the logs, as this was an index of the cohesion and strength of the rock, and the comparatively long core pieces recovered also showed the effective sheet joint spacing. The only information available from the driller indicated 'easy drilling' for all holes.

Apart from fairly wide variations in the grain sizes, the rock types also showed considerable changes in each hole. However the boundaries were not structural weaknesses and the fine-grained basic lenses especially were considered advantageous.

The cores were split, which meant breaking firstly into pieces of less than 4 inches. One half of the split sample was retained in core boxes for record purposes. The other portion was divided into the same classes as shown on the logs, but every alternate piece of core was placed in a bulk sample. This bulk sample which constituted one quarter of the total core, was crushed and given an L.A. test, as were any of the class samples of sufficient size to make up a test. The smaller sized class samples for various bores were grouped together to make test samples. Table 1 gives details of the various test results. It is notable that all the samples except the pegmatite gave acceptable test results. However there seems to be little particular virtue in an L.A. of 39·5 as compared with a figure of 40·8; the difference can barely be called significant.

Table 1

LOS ANGELES ABRASION TEST RESULTS

Location	Length	Class of Sample	Grain Size %			L.A. Result
			Fine	Medium	Coarse	
DH33	49	Composite ¼ core	43	40	13	35.0
DH32	50	Composite ¼ core	42	26	10	38.5
DH31	30	Composite ¼ core	17	68	15	35.0
DH30	30	Composite ¼ core	16	66	17	39.5
DH31, 32, 33	....	Pegmatite	....	....	....	40.8
DH30, 31, 32	....	Medium-coarse	....	....	....	38.0
Average of ¼ core samples						37.8

Apart from the pegmatite result, there is little significant correlation between grain size and Los Angeles abrasion loss from these figures. The other obvious cause of weakening of the rock fabric is breakdown by physical and chemical weathering because of the incidence of sheet joints. In order to evaluate this fully, the core for the top 5 to 10 feet of each hole would have to be discarded before analysis.

From the cores, the following average composition of the quarry rock has been calculated :

	%
fine-grained granite	28
medium-grained granite	41
coarse-grained granite	11
pegmatite	4
basic lenses	16
	100

At the conclusion of the testing programme there was a general agreement that the Rifle Range quarry offered the best prospects of obtaining stone to conform to the specification. In spite of the wide variations of rock type, the reasonably good L.A. test results, the predominance of medium and fine-grained classes of rock, and the restriction of weathering to the top five of 50 feet, were decisive. It was considered that an L.A. of about 40 would be obtained on actual working.

PLANT AND OPERATION

Crushing Plant

The flow sheet for the quarry is detailed in Plate 16. The layout is conventional and efficient under normal circumstances. The primary, a jaw crusher (36 inches x 42 inches), is set for a 6 inch opening and is fed at ⅔ choke. There are two secondary cone crushers, Symons and TY, set at 1⅛ inches, and the product is then conveyed to vibrating screens. The +2 inch rock is returned to the Symons cone crusher, and this fraction is about 10 to 15 % of discharge from the cones. There are two screens of 2¼ inches and 2 inches in the upper screen, and ¾ inch, ½ inch and ⅜ inch in the lower screen. The ballast product, −2 inches +⅜ inch is conveyed to the stock pile, the −⅜ inch is conveyed to the reject pile, and these fines make up to 30% of the input.

QUARRY APPRAISAL

Quarry

The thickness of the layer of weathered rock has decreased as the height of the face increased, as the quarry moved into the granite hill. With the face height at 20 feet, from 10 to 15 feet of sheeted, weathered rock was exposed. At the present face height of 50 feet, about 5 to 8 feet of rock has been affected by weathering. There are two areas of deeper weathering, and in both cases vertical jointing is associated with minor shearing. These areas can be readily followed on the ground surface as depressions in the rock. On the basis that the strongest rock is topographically most prominent, it appears desirable that the quarry face should follow the highest part of the rock ridge which is exposed continuously. However, nothing is known of the nature of the rock hidden under a sand cover to the west which may be indicative of a change of rock type, and as the 'rock' outcrops are generally asymmetric having a steeper face on the west side, quarrying in this direction is not recommended.

It is doubtful that an expensive quarrying operation in the removal of the top 5 feet of weathered rock would have improved the product significantly, as it is of interest to note that the L.A. losses have been fairly consistent regardless of the extent of weathered rock found in the working face at the time.

Examination of the rock pile shows that the blast hole layout is efficient, producing a reasonable balance between oversize and rock acceptable by the primary crusher. It is considered that the sand lying on the quarry floor has been produced immediately adjacent to the blasthole, rather than from general breakdown from grinding of rocks moving during blasting. There is a zone of shattered rock surrounding each blasthole, with granulation to sand size for 6 inches, and general shattering and breakage for 1 to 3 feet. This means that blasting destroys 13% of the rock in the mass of each paddock fired. Not all of this amount is left as fines on the quarry floor : much of the outer shattered zone will be loaded and processed. If we assume one quarter of the shattered zone produces sand left in the quarry, then about 10% of the throughput is already in a form to produce reject fines. As the total waste is about 30%, crushing and movement in the plant must subsequently produce 20% fines.

Granulation of the rock round the blasthole is indicative of localization of intense shock waves caused by a high explosive. A slow-acting explosive would not normally produce such shattering, but it may not produce adequate rock breakage either. It is possible that the hole diameter is too small for the type of explosive in use on this particular quarry rock and this is a matter on which further study may be warranted.

It is considered that further investigation should be done on the nature of the breakdown of the quartz grains during blasting and crushing. At present, a piece of rock is processed by (1) blasting from the face, (2) loading and dumping, (3) passage through a jaw crusher, (4) passage through a cone crusher, and (5) 10 to 15% has a further pass through a cone crusher. It is possible that progressive comminution affects the crystal fabric of the rock, and after repeated assaults the quartz grains finally give way. Alternatively this breakdown could be effective from the very beginning of quarrying, and in fact is an inherent rock weakness. In addition to the initial petrological examination further petrological examination has been commenced to determine the state of the quartz grains in rock of the following categories :

1. fresh unbroken quarry rock
2. rock blasted from the face
3. rock that has passed through the jaw crusher
4. rock that has passed the TY cone
5. rock returned from the Symons cone
6. screened ballast (+¼, —2 inch)
7. reject fines from stock pile
8. shattered rock adjacent to blast hole.

This enquiry may be of value to contractors in any future quarry work in similar rock between Northam and Kalgoorlie as it may indicate that a change of crusher type and a reduction in the number of steps in the crushing circuit would minimise the production of excessive reject fines.

Much of the quarry run material is tabular in shape ; this is a consequence of the sheet joints that appear to have a spacing of from 2 to 4 feet in the sub-surface zone. The incidence seems to be higher than was apparent from the drillholes and it is suspected that a certain amount of opening up has occurred from blasting vibrations, and also possibly from rebound or stress relief on the removal of adjacent rock. The fact that sheet joint spacing is 2 feet in the side walls and 5 feet in the main face appears to be a consequence of the shape of the rock outcrop.

A noteworthy feature is that the rocks left for secondary blasting are almost entirely of homogeneous fine-grained granite.

Cracking, where developed in the face or on the sides of blocks, is quite irregular and the breaks appear to take a preferred path through quartz segregations rather than a direct path. This suggests the action of a rather slow-acting shock wave from the explosion, as distinguished from the fast-acting, intense shock that is apparently confined to the area round the drillhole.

Crushing plant

Abrasive wear of the plant is considerable, and loader tracks, the secondary crusher wearing surfaces, and jaws of the primary all need repair before their normal span. This is caused by the abrasive action of the broken quartz grains, and this could be partly remedied by removal of fines from the circuit. The obvious solution would be to place a vibrating grizzly ahead of the primary crusher and to take the fines direct to the secondary. Another, but possibly less effective, scheme would be the use of a vibrating screen in front of the cone crushers with the rejection of —⅜ inch fines, or a separation of + and —2 inch material.

At one time notable layering of the product stockpile was apparent and there were horizontal zones of fines, smaller than the specification limits. This was related to the initial crushing and also to some extent by the movement in the pile by rubber tyred loaders pushing the product about with an action akin to autogenous grinding. This stone was re-screened to remove the excessive fines. Also the rubber tyred loaders were taken off the pile and were required to work from the sides, though it is noted that the segregation in a conical pile is automatic. Satisfactory grading of the product can be achieved by working the plant from the sides of the stockpile so that re-mixing occurs during loading.

The fines contained in the reject pile may have a future value as cement sand and for roadworks, though screening costs may make it uneconomical because local supplies are being met by A.B.M.

Results achieved

The results achieved, counted in terms of obtaining acceptable L.A. test results, have been marginal. Prior to the development of a full face, the proportion of sheeted and weathered rock in the throughput was high, and a similar situation would develop if the quarry face was advanced into lower ground. This fact then has meant a gradual improvement because of a higher proportion of good rock.

Because concern was felt as to the available quantity of rock, the quarry floor was dropped 5 feet. Although creating a drainage problem, this increased the quantity of rock available and decreased the proportion of weathered rock.

The recent recognition of vertically jointed and weathered granite in one area of the quarry has meant that selective mining has been possible, and this has assisted in raising the class of stone delivered to the crusher, although it is of interest that the average L.A. results remained practically unchanged.

The layout of the exploratory diamond drillholes was confined to areas where the full quarry face was to be developed and no holes were drilled in the entry and development section, where the face was less than 30 feet high, so that the weathering depths measured from the drillholes were far less than the thickness of sheeted and weathered rock found lower on the slopes.

In the initial opening of the quarry a considerable proportion of the stone was used in establishing all-weather haul roads and a ramp with turning area to the primary crusher. In this phase, rock as passed through the plant was screened again due to excessive fines in the stockpile.

The L.A. test results obtained from core samples, while representative of the rock types, did not show the full effect of the quarrying and crushing operation. The cores were split, crushed, and screened for the test, whereas quarry rock is blasted from the face, and reduced 2 or 3 times before reaching the desired size. The test results were not misleading as an allowance must be made for the differences in treatment. The average L.A. value obtained from the quarry throughout its working life has been 43·2 with little variation on this value. This means that the exploratory average of 37·8 has to be increased by about 5% or 6% in order to correlate the laboratory test results with tests made on production runs.

It has taken some time for the quarry routine to settle down, and for the present blasting pattern to be evolved. It is not considered that much improvement would be achieved in this regard ; possibly some slowing in the speed of the explosion could give less pulverization of face rock or possibly this could be achieved by altering the size of drillhole.

In the crushing plant experiment has been necessary to get the most effect from the crushing machines. In general it has been found that improved results were achieved by reducing the opening of the primary crusher and increasing the opening of the secondary. The screens have also been adjusted, and an improvement has resulted. The fact that a wrong shape of plate was found on the jaws of the primary crusher did not assist the contractor in maximum production and has contributed to the waste fines in the reject pile.

It would be fair comment to say that the quarry was never highly regarded, it simply was considered the best available source of rock in the area.

CONCLUSIONS AND RECOMMENDATIONS

The experience of investigation and working the quarry may be applicable to the investigation and working of other quarries of similar material.

1. The preliminary investigations at the quarry site were valid in that the site is still considered the best available. Under optimum operating conditions the quarry produces ballast barely meeting the L.A. loss requirement of the specification.

2. A figure of about 5% or 6% has to be added to the L.A. results obtained from borehole material to bring them to figures from production runs. Under normal conditions it appears that the L.A. of samples blasted from the weathered outcrop may give an indication of the L.A. value expected from the production stockpile by decreasing the value by about 2% or 3%.

3. The early results obtained from the quarry were not good. Blasthole pattern, the size of crusher openings, and screen sizes are all important variables that did not achieve optimum working efficiency until after a few month's production.

4. The high ratio of weathered to unweathered rock that exists on the lower slopes of the granite ' rocks ' was not discernible from the limited number of drillholes, which, to obtain maximum information, were drilled in positions of maximum face height.

5. A quarry face of 15 to 20 feet was developed before the operation of the crusher, and the stone was used for various construction purposes. The inherent defects in the quartz have still not been fully assessed and even an increase in height of the quarry face has not resulted in better L.A. figures.

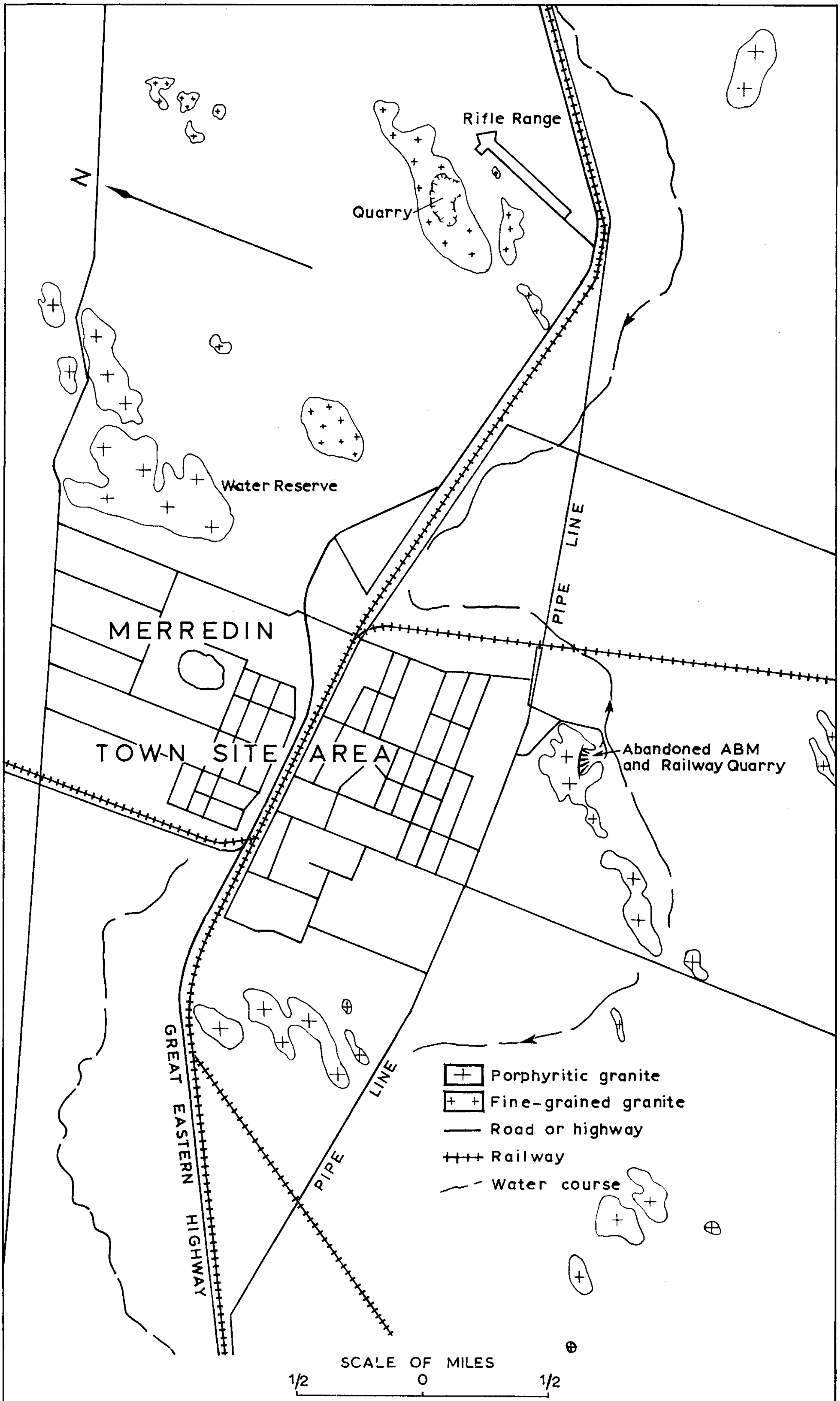
6. The height of the face of the working quarry will decrease as work proceeds southeasterly down the spine of the outcrop, and it is considered that a further cut into the quarry floor should be considered, in order to maintain the present ratio between weathered and unweathered rock.

7. For any granite quarry in the area between Northam and Kalgoorlie, one of the prime considerations should be to secure a working face at least 50 feet high, by going below ground level if possible. Work in side hill locations should be avoided and development concentrated in the topographically highest part of the ' rock,' if this does not seriously affect the quantity of stone available and make the operation expensive.

8. Provision of a vibrating grizzly in front of the primary crusher, and the provision of shaking screens before the secondary cone crushers, could possibly reduce abrasion of moving parts by removing a large proportion of quartz grit from the feed.

9. Experimentation by the contractor in a variation of the type of explosive or in the sequence of firing a blast may reduce the amount of fines produced and may be worth following up, although this may also increase the amount of secondary blasting required.

10. Petrological work has been initiated to discover the nature of the breakdown of the quartz grains. At present it is suspected that breakdown is not a cumulative process but occurs when coarse-grained crystal masses are



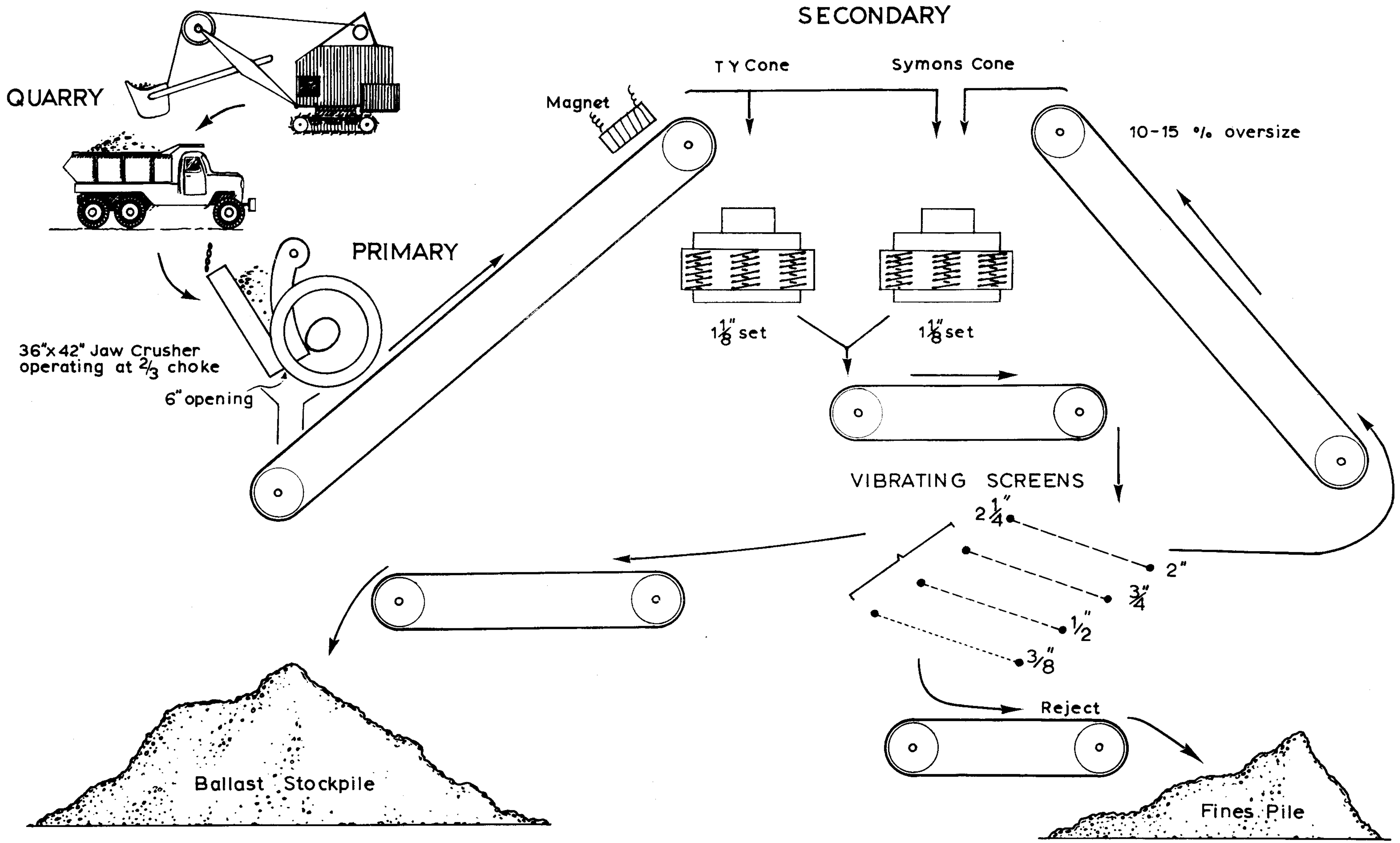
GEOLOGICAL SURVEY OF WESTERN AUSTRALIA

MERREDIN RIFLE RANGE QUARRY
LOCALITY MAP

To accompany report by F.R. Gordon 1966

9537

PLATE 16



GEOLOGICAL SURVEY OF WESTERN AUSTRALIA

MERREDIN RIFLE RANGE QUARRY
FLOW SHEET

To accompany report by F.R. Gordon 1966

9538

oriented to give a favourable path for fracturing or cracking at any of the various stages of the production process.

11. There is undoubtedly scope for a lot of research on the investigation of quarry sites.

Perhaps a longer tender period should be allowed, for the tenderers to make a more thorough investigation of this important and costly aspect of the contract.

Diamond drilling is one of the most useful tools and possibly large size cores could be obtained for L.A. tests that would enable 2 or 3 passes through a crushing circuit, but diamond drill bits producing core in excess of 3½ inches diameter are not normally available.

12. In the quarry operation the following items have been altered or adjusted: (i) the proportion of weathered rock has decreased; (ii) the screen size has been changed to allow a wider grading; (iii) the convexity of the crusher jaws has been varied; (iv) the opening of the primary has been decreased and the opening of the secondary increased; (v) the spacing, layout, and loading of the blastholes has been altered.

All these variables have been altered in a manner which should have given a better L.A. result, but this has not eventuated. Either some of the variables worked in the wrong direction, or an unknown factor such as rock type has adversely influenced results.

13. It is possible that blasting has an effect on the quarry rock akin to moderate weathering.

14. The problem of accurate prediction of L.A. results from initial investigations may have to await further advances in rock mechanics. Uniaxial compression tests may be of use as there is certainly a correlation between compressive strength and drillability and ease of drilling is surely an index of the toughness and cohesion of a rock. Conversely measurement of speed of drilling could be of value, especially if a body of information is built up. The Rifle Range quarry granite drills at 2·05 feet per hour.

15. For the granite 'rocks,' the size of an outcrop and its resistance to weathering are two factors that determine the height. The topography tends to reflect the character of the underlying rock, a smooth surface indicating a homogenous composition whereas depressions indicate variety.

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—— 1965, Quarry sites between Koolyanobbing and Kalgoorlie, Standard Gauge Railway: West. Australia Geol. Survey Rec. 1965/33 (unpublished).

ASPECTS OF STABILITY OF ROCK CUTS NEAR KELLERBERRIN, STANDARD GAUGE RAIL PROJECT

by F. R. Gordon

INTRODUCTION

The relatively high granite hills to the west of Kellerberrin have necessitated a considerable deviation of the Standard Gauge Railway from the existing line, in order to maintain ruling grade and to minimize rock excavation. The final location involved two rock cuttings which have been completed; the track has been laid and ballasted and the line is in full use.

The cutting known as K4 is approximately 5 miles southwest of Kellerberrin and extends from K4 miles 62 chains to K5 miles 24 chains with a maximum depth of cut of 40 feet at K5 miles 14 chains. The more easterly cutting, known as K8, extends from K7 miles 59 chains to K8 miles 23 chains with a maximum depth of cut of 30 feet at K7 miles 77 chains.

Because a softer basic lens was encountered in the predominant granite of the K8 cutting, the cuttings were briefly examined geologically during excavation, as it was feared that the batter angle of 60° would have to be adjusted. At the completion of excavation the two cuttings were examined in the company of Mr. G. Preston, Senior Resident Engineer for the consultants, Maunsell and Partners. The purpose was to define any areas or blocks liable to rock fall or sliding, and all suspect areas were numbered with red paint to allow ready identification, if and when remedial works were instituted.

GEOLOGY

Rock types

The area was examined by geological reconnaissance during the preliminary studies for the location of the Kellerberrin Deviation (Gordon, 1963).

The cuttings are situated about half way down a broad, gently sloping, southerly facing hill slope, and rock is very close to the surface.

In cutting K4, granite gneiss is remarkably uniform throughout, but the rock can be divided into a number of zones, distinguished by the amount of physical or chemical weathering that has been dominant. The rock is a light-grey, weakly banded granite gneiss with biotite segregations from 1 to 2 feet apart.

The rock is divided by several major sheet joints roughly parallel to the ground surface and these have controlled weathering by limiting the movement of water. The various types of rock resulting from chemical weathering applicable to the area are shown in Table 1.

Table 1
WEATHERING OF GRANITE GNEISS, KELLERBERRIN AREA

Completely weathered	Completely altered to a sandy clay, disintegrates in water.
Highly weathered	Intensely weathered, with recognizable rock structure, can be broken in the hand.
Moderately weathered	Considerably weathered but core pieces cannot be broken in the hand.
Slightly weathered	Rock is limonite-stained throughout, feldspars are cloudy.
Limonite stained joints	Joint faces coated, granite blocks between joints are unweathered.
Fresh rock	Unweathered joint coatings may be of clay, chlorite, pyrite.

In the cutting at K8 there are considerable variations in both the rock types and the degree of weathering. There are three main types of granite: (1) an equigranular light-grey granite with occasional large basic lenses (0 to 9½ chains); (2) a light-grey foliated granite gneiss, with a foliation dip of about 70° to the west, which is in places considerably distorted (9½ chains to 24·2 chains); (3) a medium to coarse-grained porphyritic granite, light-grey in colour, that occurs from 24·2 chains to the end of the cutting. Three dolerite dykes traverse the cutting, all of which strike 240°, almost at right angles across the cutting, and dip at 80° to the east: (i) a dyke 1 foot wide on the left hand side (LHS) at 24·3 chains thins to 6 inches wide on the right hand side (RHS); (ii) a 2-foot 2-inch wide dyke is located at 15·7 chains on the LHS; (iii) an 8-inch wide dyke is found at 14·4 chains on the LHS.

There is a large basic body between 8½ and 9½ chains with irregular margins and intrusions of pegmatite and big masses of vein quartz. A definite foliation, which strikes across the cut and dips at 30° to the west can be seen in places. A major pegmatite dyke extends from 9·25 to 9·55 chains (i.e. about 21 feet wide) and contains large basic inclusions. Quartz and feldspar make up the bulk of the rock, but biotite and magnetite segregations are common.

Geomechanical data

Faulting and folding are not of importance in the mechanical configuration of the two cuttings, nor does the type of rock appear to affect the inherent stability.

Jointing is the dominant structural feature, controlling the stability of individual blocks of rock, and indirectly influencing the stability of rock and debris masses by controlling water movement which accelerates weathering.

The most important joints are the sheet joints which are mostly parallel to the existing ground surface. Although they are not as continuous as the joints developed in steeper topography, the joints have allowed weathering to develop on either side of the opening, and 9-inch wide seams of completely decomposed granite (as a sandy kaolin clay) are common. As is usual in this type of joint, the incidence is greatest near the ground surface and the potentially unstable areas are usually concentrated in the top 10 feet of the cutting.

Most of the stability problems are posed by large individual blocks of rock that are lying on the sheet joint clay seam lying in the dip into the cut on the highest (north) wall. Another common type of instability has resulted from overhangs developing where blocks of relatively fresh rock have resisted blasting while the sheet joint clay seam and the slightly to moderately weathered rock underneath has been removed (Plate 17).

The second most numerous type of stability problem involves individual blocks of rock that are separated by normal jointing or are standing out of the walls, and have a steep-dipping exfoliation joint at the rear. The number of these joints in cutting K4 is unusual, and it is almost certain that the technique of pre-splitting, used exclusively in this cutting, is responsible for the cracking and joint formation. Exfoliation joints of this type are developed parallel to the face of the excavation, that is, parallel to the initial slot, and are considered a post-excavation relaxation feature, analogous to the rebound mechanism of large scale sheet joints. What is surprising is a large number so close to ground surface, and the cause is considered to be the intensity of the explosive effort used to form the primary slot, followed by general excavation.

Overshooting the toe of the batter to give an over-steep face is usually achieved by faulty excavation methods. Overloading of blast holes, or underloading followed by trimming, are the normal causes. However, examination in the cuttings near Kellerberrin has shown that certain aspects of oversteep batter toes is as much a problem of design as of excavation method. The cutting of a vertically walled ditch at the foot of the batter inevitably results in a reduction of effective strength of the rock. If on completion of the excavation the toe is slightly full, which would be a reasonable condition to avoid shattering from the rose of joints resulting from blasting (Gordon, 1966), then excavation of the ditch would further accentuate the condition at the toe (Figure 8).

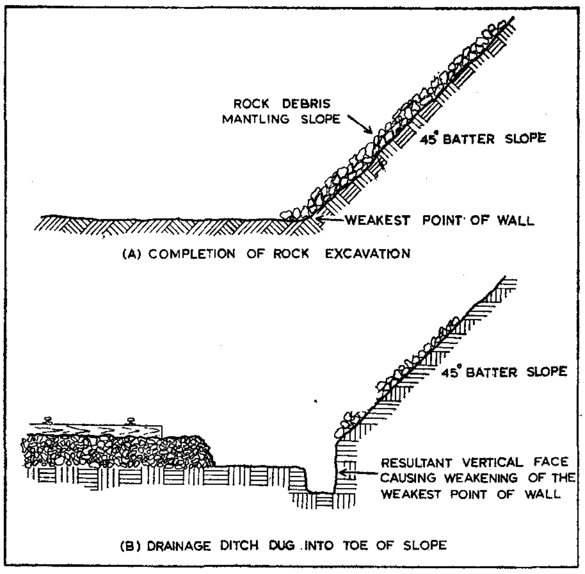

FIGURE 8 : KELLERBERRIN ROCK CUTTINGS; SECTIONS ACROSS CUTTINGS IN WEATHERED ROCK AREAS

The effect of battering the weathered rock back to 45° (in this case) is completely nullified.

Of minor importance in the two cuttings are the more conventional types of block instability. These include intersection of main joint planes, overshot batter toe giving oversteep faces, shattered rock, and clay seams other than in sheet joints.

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GEOLOGICAL INVESTIGATION OF MOOCHALABRA CREEK DAM SITE

by J. D. Wyatt

SUMMARY

To improve the Wyndham water supply, the Public Works Department intends to dam Moochalabra Creek, a tributary of the King River.

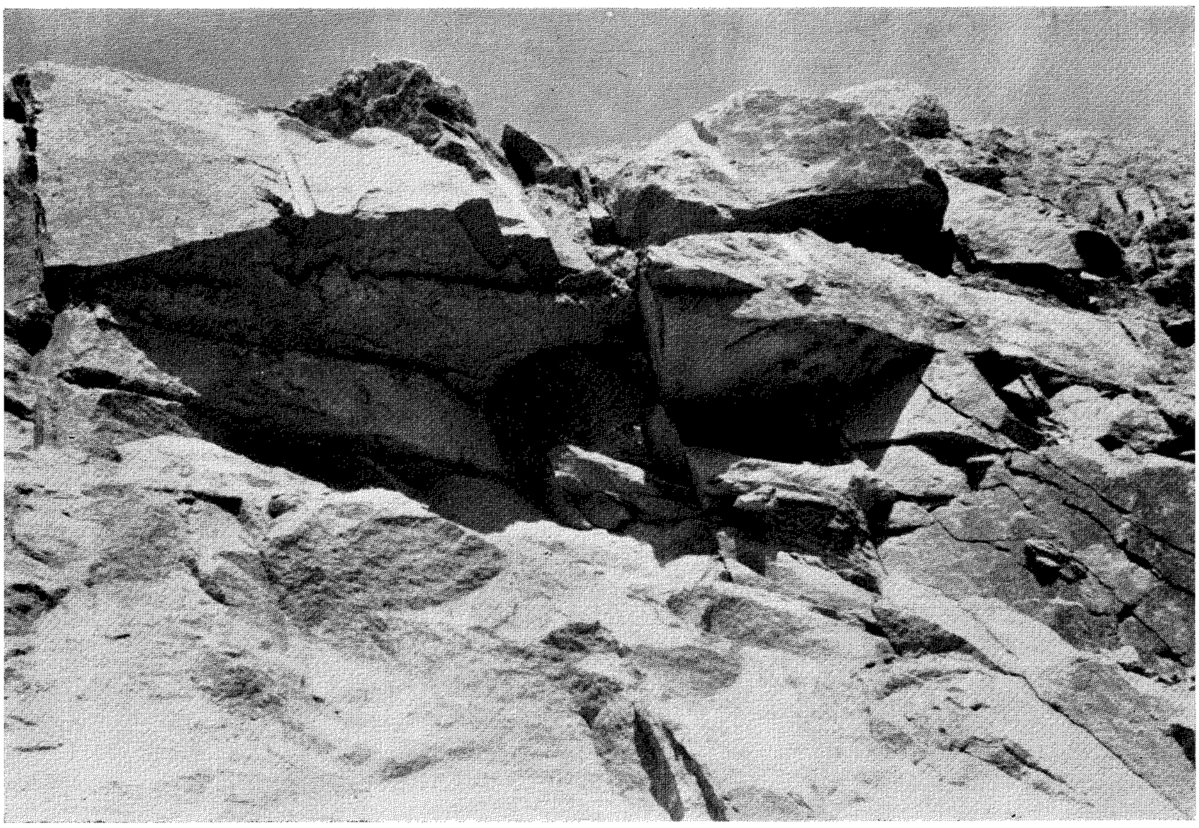
Detailed mapping and five diamond drillholes were used in the investigation of a trial centre line. The dam is to be constructed of rockfill with an impervious clay core, and these materials will be obtained close to the dam site.

The embankment is expected to rise 60 feet above the present creek bed, to an R.L. of 106 feet. To cope with the wet season flooding, a spillway will be excavated on the left bank of the creek.

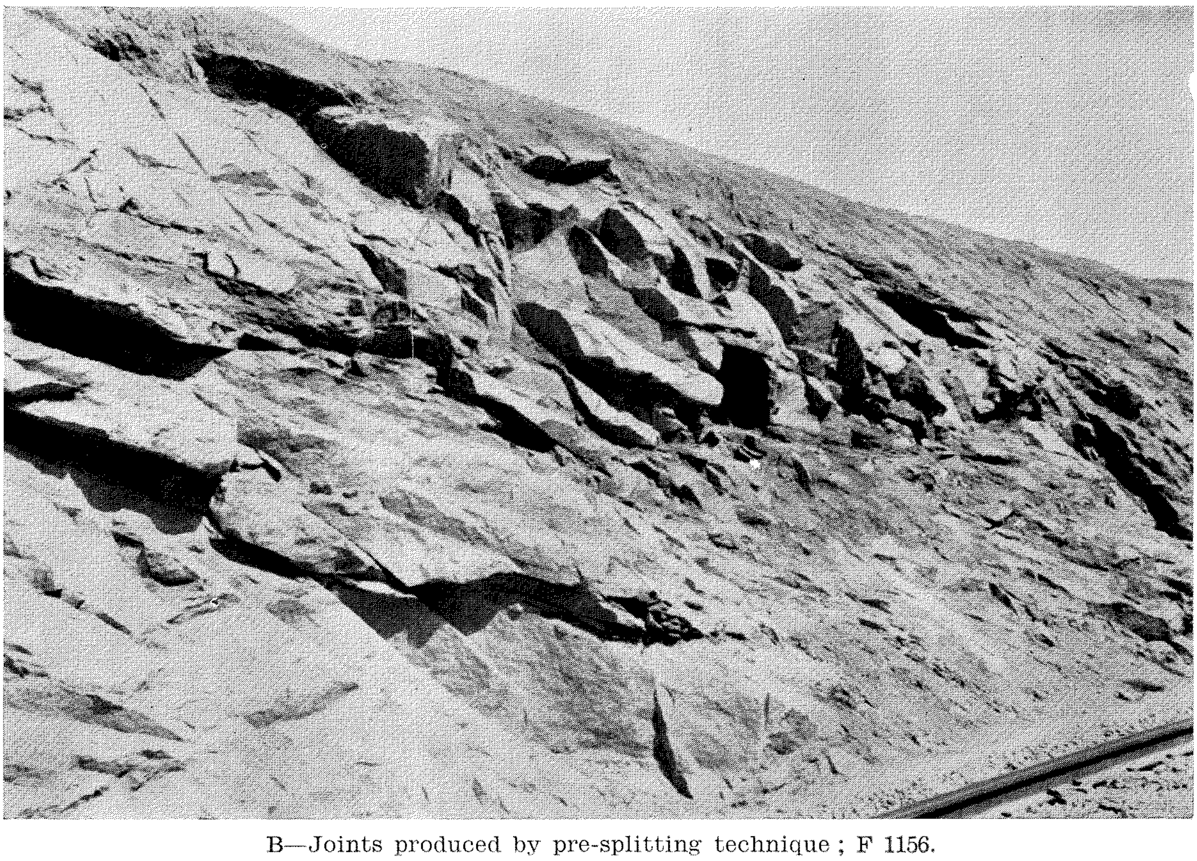
The foundations of the proposed dam and spillway will be composed of a closely jointed and well bedded sandstone containing thin siltstone interbeds. Jointly is mainly restricted to two major sets, one striking north and the other east.

Three major faults were mapped just upstream from the proposed site and one of these may prove to be a troublesome leakage path from the reservoir.

Important disadvantages of the site include a steep cliff forming the right abutment, two faults upstream from the trial centre line, and the permeability of the abutments.



A—Overhangs caused by the presence of sheet joints channelling blasting. A weathered clay seam on a sheet joint 6 inches thick is seen immediately under the main overhang ; F 1155.



B—Joints produced by pre-splitting technique ; F 1156.

INTRODUCTION

A dam to supply water to Wyndham is proposed for a site on Moochalabra Creek, a tributary of the King River. The site is 15 miles south of the town.

Access from Wyndham is by way of the Great Northern Highway to the 8 mile peg, thence 14 miles along an all-weather gravel road to the mouth of Moochalabra Creek. From this point to the proposed dam site the final 1·3 miles along the creek bed can be negotiated only by 4-wheel drive vehicles.

This report sets out the results of plane table geological mapping on a scale of 1 inch to 50 feet, and includes diamond drilling information.

Regional geology of the area is covered in a report of the Bureau of Mineral Resources (Plumb and Veevers, 1965). In 1965 a short visit to the site was made by F. R. Gordon and his recommendations were used as a basis for the more detailed mapping and diamond drilling investigations completed later in 1966 (Gordon, 1966).

GEOLOGICAL SETTING

TOPOGRAPHY AND DRAINAGE

The topography is rugged as a result of the deep dissection of the Kimberley Plateau. To the west of the proposed dam site the plateau is separated by a fault scarp from the tidal flats of the Cambridge Gulf Lowlands.

The area is drained by short, intermittent, but actively eroding streams. The drainage is dendritic, except in the northwestern part of the plateau where most of the creeks flow either west or northwest off the elevated land down to the tidal flats.

Shortly before joining the King River, the north-westerly flowing Moochalabra Creek swings sharply south around a low spur, which is opposed on the right bank of the creek by an almost sheer cliff face rising some 150 feet above the river bed. This is the site of the proposed dam and spillway, through which a trial centre line, B_1–B_3, has been laid out.

Downstream from the pegged centre line, Moochalabra Creek flows parallel to the King River, but in an opposite direction, and is separated from it by a steep, narrow ridge. About one mile further downstream the valley takes a right angled swing to the west to join the King River, as a series of poorly defined channels flowing across a small tidal flat.

At the proposed dam site the valley is asymmetric having a steep right abutment and a flat (6°) left abutment.

Several permanent pools occur along the river channel, both upstream and downstream from the pegged centre line, and these are invariably located at the base of the steep cliff sections. The pools have almost certainly resulted from an increase in the rate of erosion, where the river has impinged on the outer side of a bend. Such a pool occurs on the right side of the river bed at the proposed dam site.

ROCK TYPES

Unconsolidated sediments in the river channel overlie a silty sandstone (the Pentecost Sandstone of Plumb and Veevers, 1965), which has been intruded by a number of quartz veins.

On the western side of the saddle centred about 400N 100W, a small outcrop of sandstone with sandy shale interbeds has been mapped (Plate 18).

Alluvium

The bed of Moochalabra Creek is covered with alluvium about 10 feet thick. It is poorly sorted and the composition ranges from large blocks of sandstone (10 feet x 8 feet x 2 feet), down to fine-grained silty sand. The most frequent sizes encountered are fragments 9 inches and 12 inches square.

The upper 2 feet of the alluvium usually consists of a layer of rounded boulders, cobbles, and pebbles, in places overlain by sand which has been partly stabilized by vegetation.

Pentecost Sandstone

This is the dominant rock type exposed at the dam site. It is a fine to medium-grained rock, containing fine-grained silty interbeds. Ripple marks and current bedding are common.

The bedding dip is usually west at between 5° to 15° and the strike N25°E (Figure 9). The thickness of the beds varies with the grain size. The more silty sandstones are generally thinly-bedded with partings every 3 inches to 6 inches, whereas the coarser-grained blocky sandstones have major beds up to 5 feet thick, but with discontinuous partings only 12 inches to 24 inches apart.

In some of the steeper sections of the right abutment cliff face, along trial centre line B_1–B_3, the thin-bedded, silty sandstones have been eroded back into the cliff as much as 10 feet to leave overhangs.

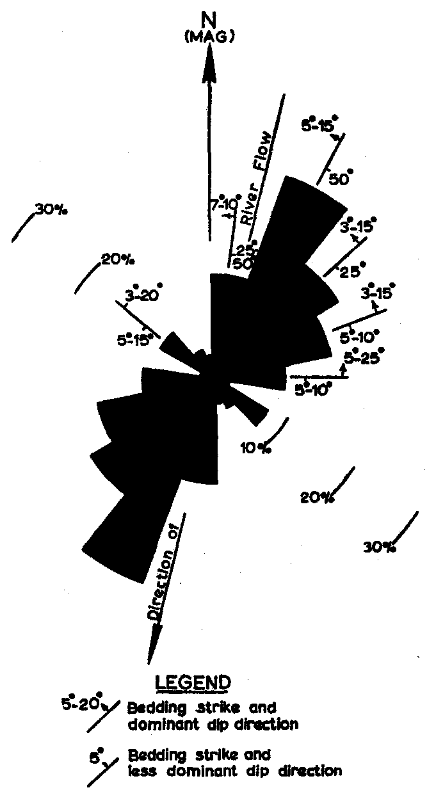


FIGURE 9: BEDDING STRIKE ROSETTE FROM 103 READINGS IN PENTECOST SANDSTONE, MOOCHALABRA CREEK

Mendena Formation

An exposure of silty sandstone with purple shale beds occurs at 000N 400W on the western side of Fault No. 1. The bedding dip and strike is variable because of the proximity of Fault No. 1. On the basis of lithology and position with regard to the Pentecost Sandstone, the rocks are considered to belong to the Mendena Formation.

Quartz veins

Quartz veins are common near the proposed dam site. One of these was traced continuously over a distance of 1,000 feet and intermittently for a further 700 feet. The veins occur as single and multiple intrusions, usually along the north-trending joint system, and are commonly between 6 and 12 inches wide. All are steeply dipping and some show slicken-sides which indicate movement east-side-north, or east-block-down.

FAULTING

There are three main faults in the area covered by the detailed investigations, the largest (Fault No. 1) forming the western boundary to the mapping.

Fault No. 1 forms a steep scarp just east of the main access track from Wyndham to the King River Pumping Station ; it strikes north and probably has a steep dip. It is not expected that this fault will have any effect on the construction of the proposed rockfill dam.

Fault No. 2 strikes N26°E with a vertical dip and passes along the eastern side of the topographic saddle. It appears to have been formed contemporaneously with Fault No. 1.

In the vicinity of 550N 120E, Fault No. 2 has a cemented fault breccia zone which ranges between 2 and 15 feet in width. It is difficult to trace in a downstream direction, but as it was not intersected in drillhole No. 1, it is probable that Fault No. 2 has been offset south-block-east by movement along Fault No. 3, although the direction and amount of movement is not precisely known.

Fault No. 3 located about 150N 000E, has a strike of N65°E and a near vertical dip. Water tests carried out in drillhole 4, which passed through this fault zone, show the fault to be a potential leakage path for water stored in the reservoir. The distance from one side of the saddle to the other along the strike of the fault is about 700 feet. The fault movement is unknown, but from topographic evidence appears to be south-block-east. No indication of this fault is apparent on the left side of the river.

JOINTING

A total of 280 joint readings were taken from every major outcrop of sandstone in the area of the dam site. The joint rosette (Figure 10) prepared from these readings clearly shows the existence of two prominent joint sets :

North strike, dipping 70°W—55°E
East strike, dipping 80°N—75°S

The joints striking north are usually less frequent than those striking east. Joint frequencies range from one joint every ½ inch in the thin-bedded finer-grained sandstones to one joint every 60 inches in the thick-bedded sandstones.

The jointing planes are open as much as 12 inches and are usually iron-stained. Most joint surfaces are free from clay decomposition products, but many are filled with thin quartz veinlets.

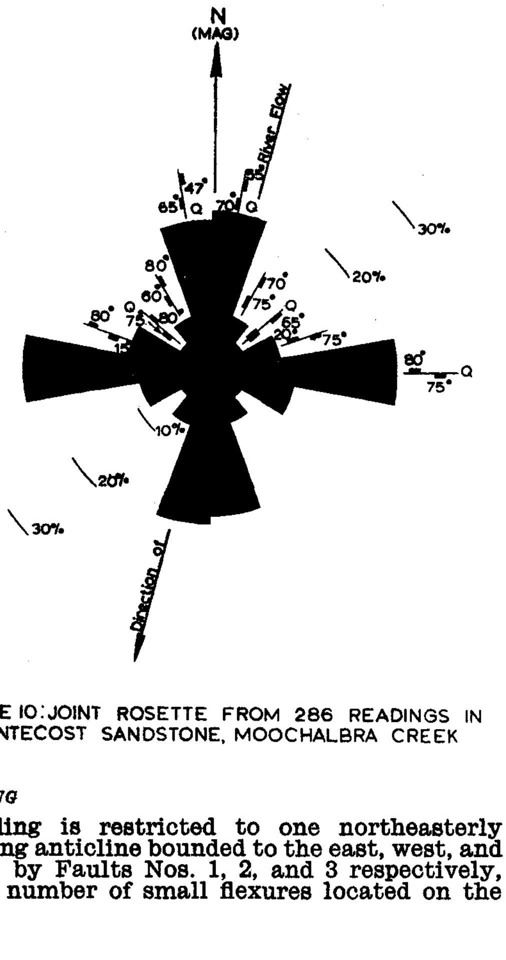


FIGURE 10: JOINT ROSETTE FROM 286 READINGS IN PENTECOST SANDSTONE, MOOCHALBRA CREEK

FOLDING

Folding is restricted to one northeasterly trending anticline bounded to the east, west, and south, by Faults Nos. 1, 2, and 3 respectively, and a number of small flexures located on the right bank of Moochalabra Creek, upstream from the trial centreline.

Anticlinal folding has caused separation between the major bedding planes of the Pentecost Sandstone, together with the formation of numerous closely spaced tension cracks, which usually do not continue through more than one bed.

SUBSURFACE INVESTIGATIONS

PITS

Two bulldozer pits were excavated in the bed of Moochalabra Creek just downstream from trial centre line B_1–B_3 (Plate 19). Both pits exposed bedrock between 8 and 12 feet below the river bed. The river alluvium in the walls of these excavations was composed of boulders, cobbles, pebbles, and about 30% sand.

DIAMOND DRILLING

Drillhole 1 was drilled from the bottom of one of the bulldozed pits, beneath the river to a point some 30 feet beyond the vertical cliff forming the right abutment.

It was expected that the breccia zone of Fault No. 2 would be intersected, but instead only a few small clay-filled shears were noted. Most of the drill core was composed of a relatively massive pink and white sandstone, in places highly silicified.

Water testing of this hole showed that between 8 feet and 108 feet drill depth, water losses ranged from 8 to 40 lugeons with varying water pressures. Below 108 feet water losses fell to less than 1 lugeon.

Drillhole 2 was located on the left abutment and drilled vertically to a depth of 54 feet 7 inches.

Core losses of 3 feet 6 inches occurred in the initial 6 feet of drilling, and an examination of the hole showed that this loss was a result of deep weathering of some of the sandstone horizons. Throughout the length of the hole these highly weathered zones, as well as thin-bedded silty partings are common.

Water pressure tests carried out between 8 feet and 45 feet showed losses of between 15 to 40 lugeons. Below 45 feet losses dropped to less than 1 lugeon.

Drillhole 3 was located about the centre of the proposed spillway site, and drilled vertically to a depth of 35 feet.

The core was broken and in places thin-bedded, but the sandstone was generally more sound than that intersected in drillhole 2.

Water pressure testing between 8 feet and 25 feet showed a loss of 17 lugeons, but from 25 feet to 35 feet water losses increased to 30 lugeons.

Drillhole 4 was located on the topographic saddle separating Moochalabra Creek from the King River, and was designed to investigate Fault No. 3 and the right abutment of the proposed dam at river bed level.

The fault was intersected as a 14 feet wide zone of intermittent brecciation and silification, between 91 feet and 112 feet 6 inches drill depth.

Water pressure testing between 8 feet and 112 feet showed losses of up to 18 lugeons. Past the fault zone water losses dropped to 1·5 lugeons.

Drillhole 5 was designed to investigate the right abutment ; it was drilled from the top of the steep cliff face and laid out to intersect with drillhole 1.

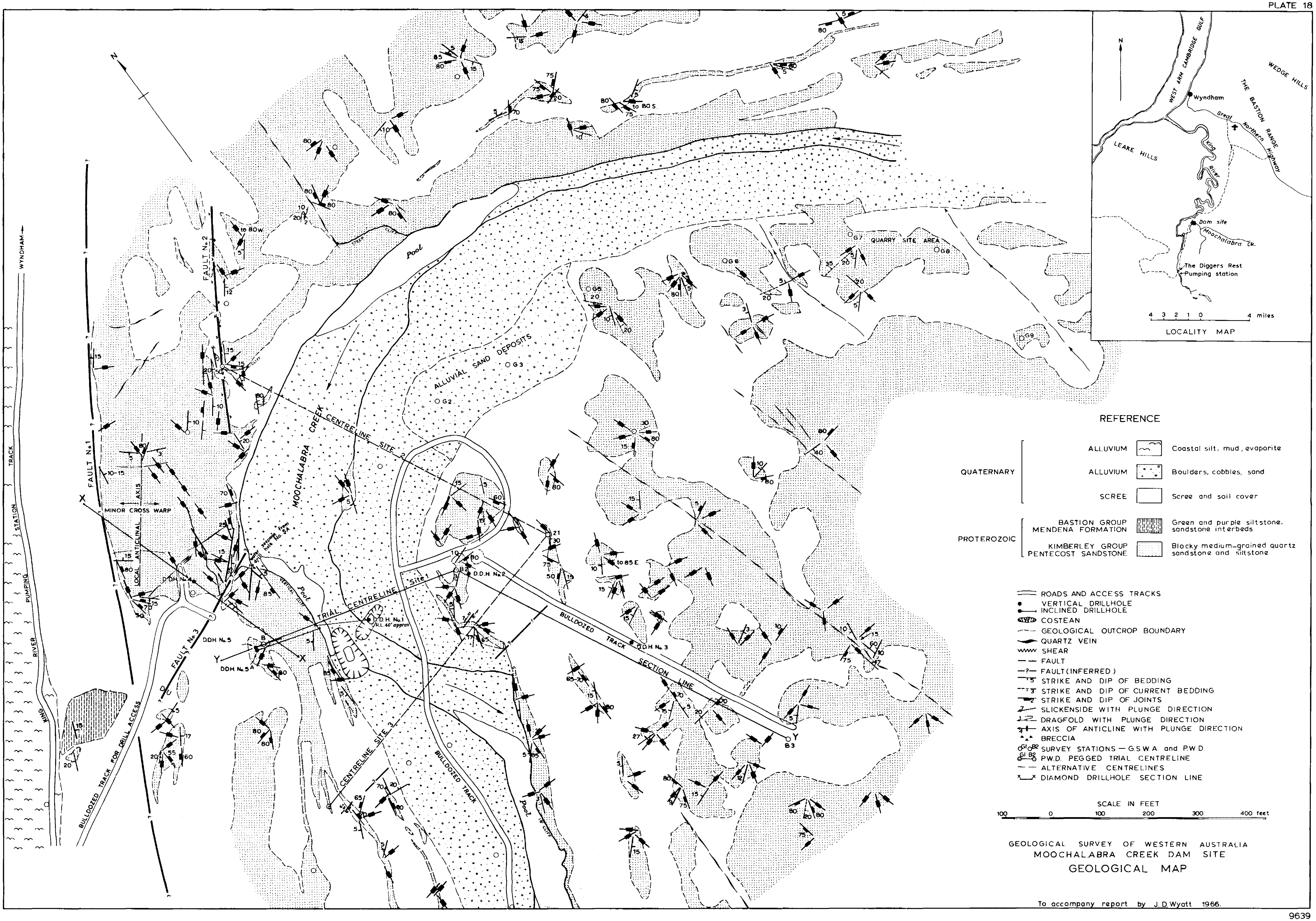
At a depth of 108 feet 3 inches, two diamond drill bits were lost down the hole and it was abandoned.

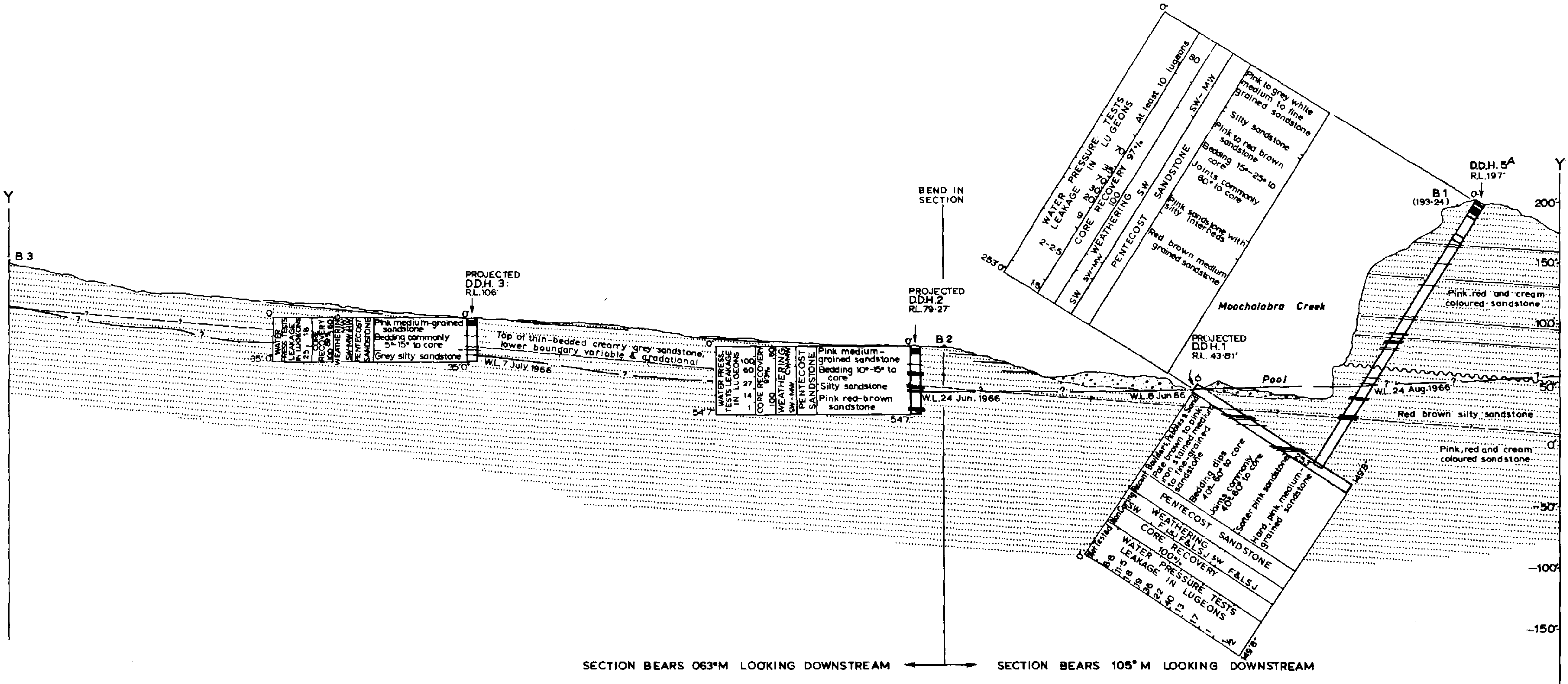
The hole was surveyed for dip at 100 feet but there was no measurable deviation.

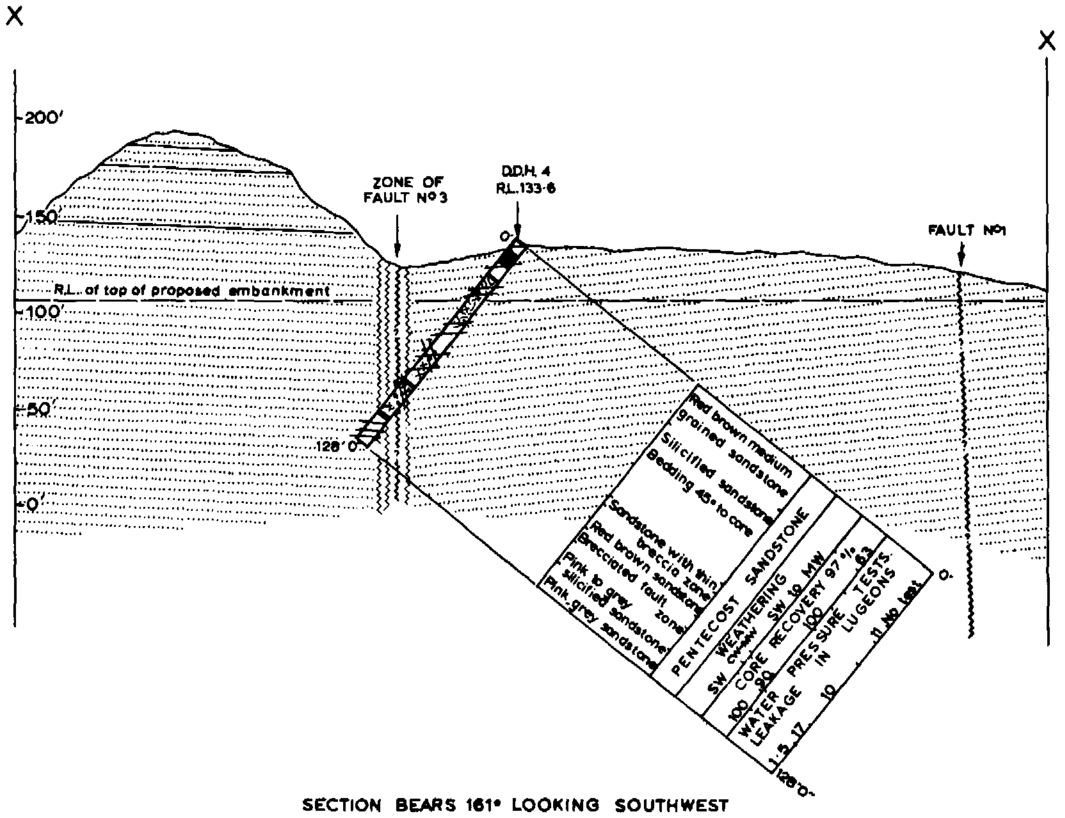
Drillhole 5A was put down after hole 5 was abandoned. The results down to 100 feet were similar.

Throughout drilling, water could be seen issuing from numerous joint, bedding, and fault planes, as far away as 180 feet from the collar of the hole.

Water pressure testing between 20 feet and 100 feet drill depth, showed a loss of about 15 lugeons, with the pump at maximum output. The maximum possible loss was probably much greater.


N
WYNDHAM
TRACK
STATION
PUMPING
RIVER
KING
FAULT No 1
FAULT No 2
FAULT No 3
LOCAL ANTICLINAL AXIS
MINOR CROSS WARP
BULLDOZED TRACK FOR DRILL ACCESS
D.D.H. No 4
D.D.H. No 5
D.D.H. No 1
D.D.H. No 2
D.D.H. No 3
TRIAL CENTRELINE Site 1
CENTRELINE SITE 2
CENTRELINE SITE 3
MOOCHALABRA CREEK
ALLUVIAL SAND DEPOSITS
Pool
BULLDOZED TRACK
BULLDOZED TRACK SECTION LINE
QUARRY SITE AREA
G2
G3
G5
G6
G7
G8
G9
B3
X
Y
WEST ARM CAMBRIDGE GULF
Wyndham
WEDGE HILLS
THE BASTION RANGE
Great Northern Highway
LEAKE HILLS
King River
Dam site
Moochalabra Ck.
The Diggers Rest Pumping station
4 3 2 1 0 4 miles
LOCALITY MAP
REFERENCE
QUATERNARY
ALLUVIUM
Coastal silt, mud, evaporite
ALLUVIUM
Boulders, cobbles, sand
SCREE
Scree and soil cover
PROTEROZOIC
BASTION GROUP MENDENA FORMATION
Green and purple siltstone, sandstone interbeds
KIMBERLEY GROUP PENTECOST SANDSTONE
Blocky medium-grained quartz sandstone and siltstone
ROADS AND ACCESS TRACKS
VERTICAL DRILLHOLE
INCLINED DRILLHOLE
COSTEAN
GEOLOGICAL OUTCROP BOUNDARY
QUARTZ VEIN
SHEAR
FAULT
FAULT (INFERRED)
STRIKE AND DIP OF BEDDING
STRIKE AND DIP OF CURRENT BEDDING
STRIKE AND DIP OF JOINTS
SLICKENSIDE WITH PLUNGE DIRECTION
DRAGFOLD WITH PLUNGE DIRECTION
AXIS OF ANTICLINE WITH PLUNGE DIRECTION
BRECCIA
SURVEY STATIONS — G.S.W.A. and P.W.D.
P.W.D. PEGGED TRIAL CENTRELINE
ALTERNATIVE CENTRELINES
DIAMOND DRILLHOLE SECTION LINE
SCALE IN FEET
100 0 100 200 300 400 feet
GEOLOGICAL SURVEY OF WESTERN AUSTRALIA
MOOCHALABRA CREEK DAM SITE
GEOLOGICAL MAP
To accompany report by J. D. Wyatt 1966.





NOTES

1. Description of material in logs of drill hole refer only to core recovered
2. Where breaks in log are indicated, core has not been recovered, due to core being ground or washed away during drilling
3. Angle of bedding and joints is the angle between joint planes and plane perpendicular to the axis of the drillhole
4. Water pressure test losses are expressed in lugeons
   One lugeon is equal to a water loss of 1 litre per minute per metre of hole at 10 times atmospheric pressure

WEATHERING

- F = Fresh rock
- LSJ = Limonite stained joints
- SW = Slightly weathered
- MW = Moderately weathered
- HW = Highly weathered
- CW = Completely weathered

REFERENCE

- Alluvium
- Pentecost Sandstone
- Geological boundary (inferred)
- Probable disconformity
- Core loss in drillhole
- Silicified sandstone
- Clay & silty partings in thin-bedded sandstone
- Brecciated sandstone
- • B2. P.W.D. survey peg
- Trace of bedding
- Water table
- Fault zone
- W.L. Water level
- R.L. Reduced level

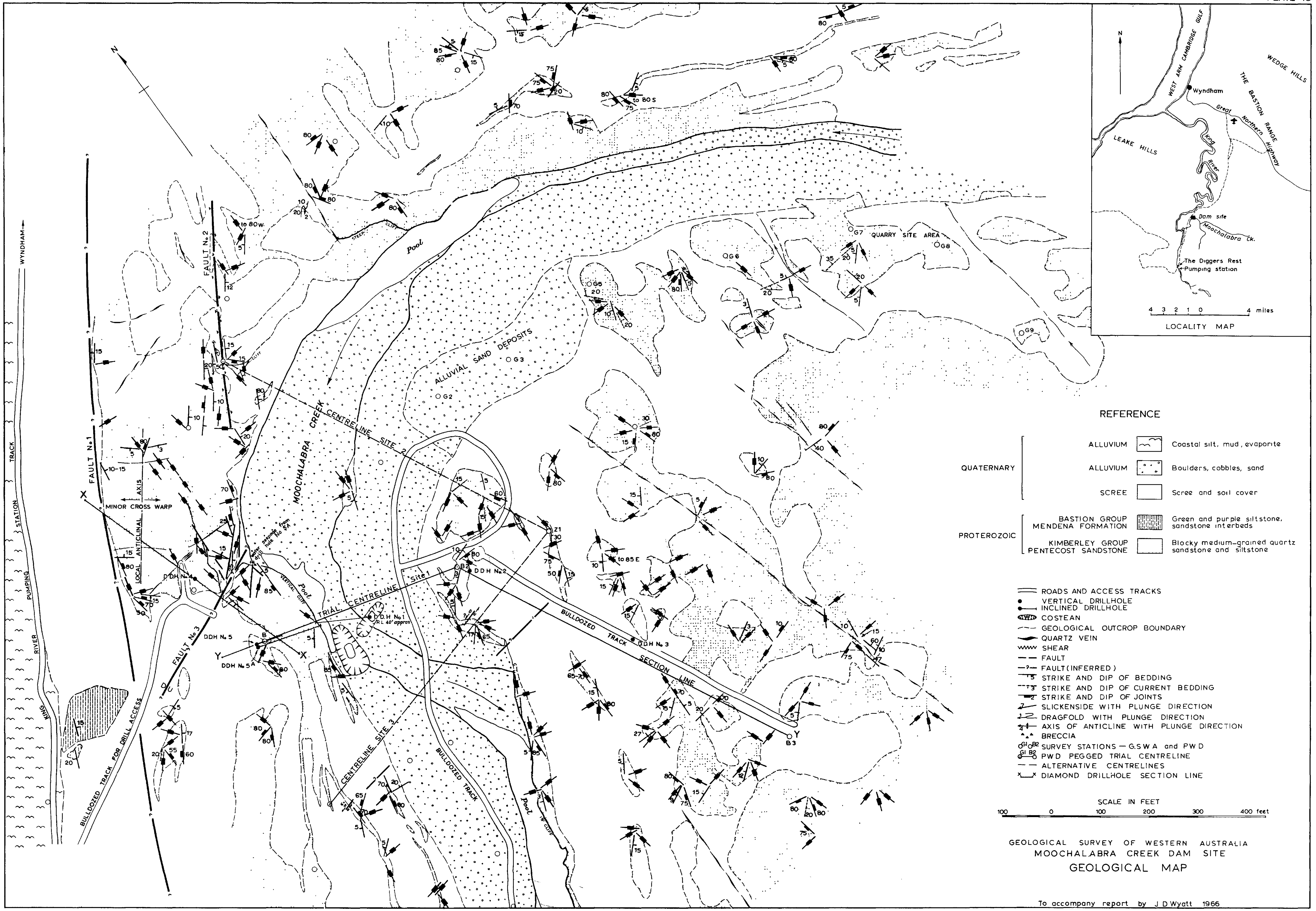
50 0 50 100 150 200 250 feet

NATURAL SCALE OF FEET

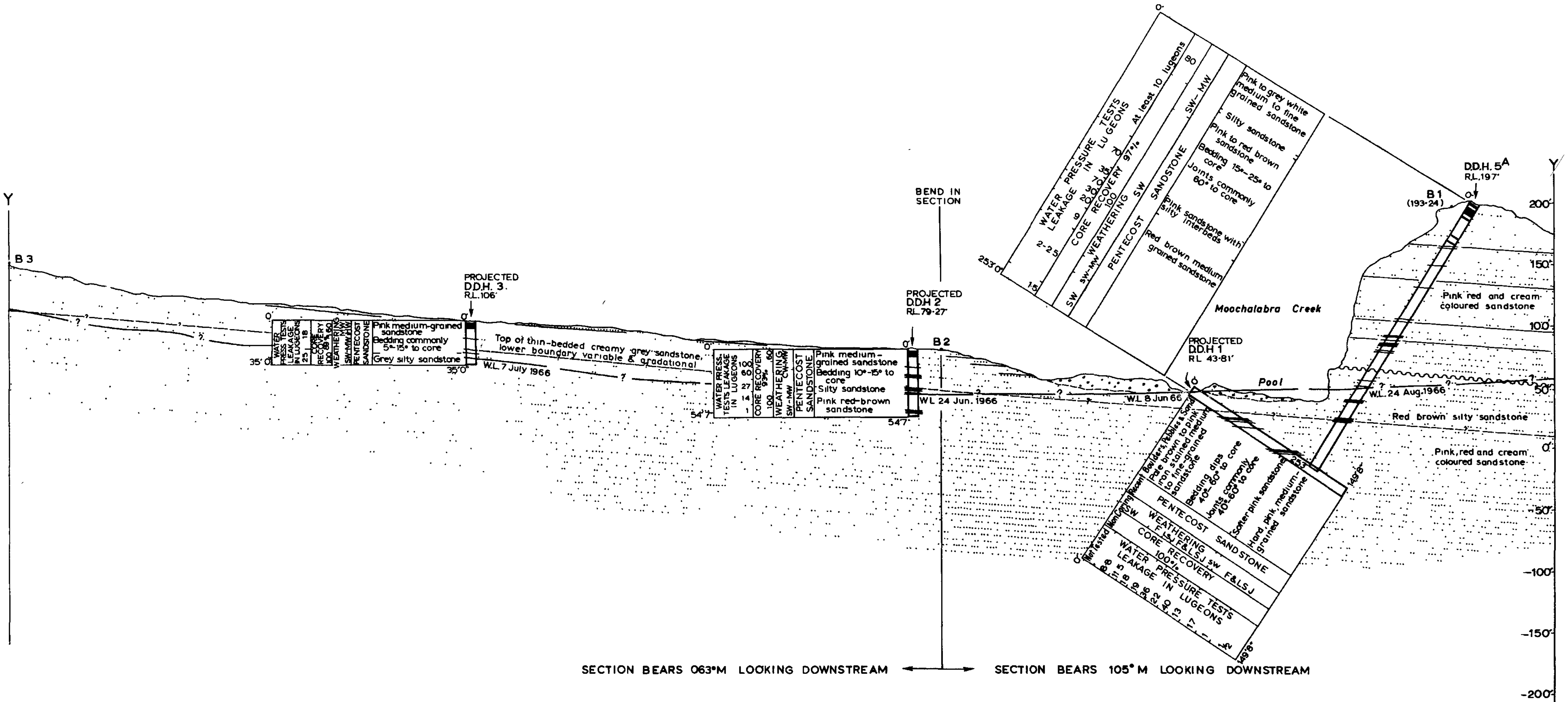
GEOLOGICAL SURVEY OF WESTERN AUSTRALIA

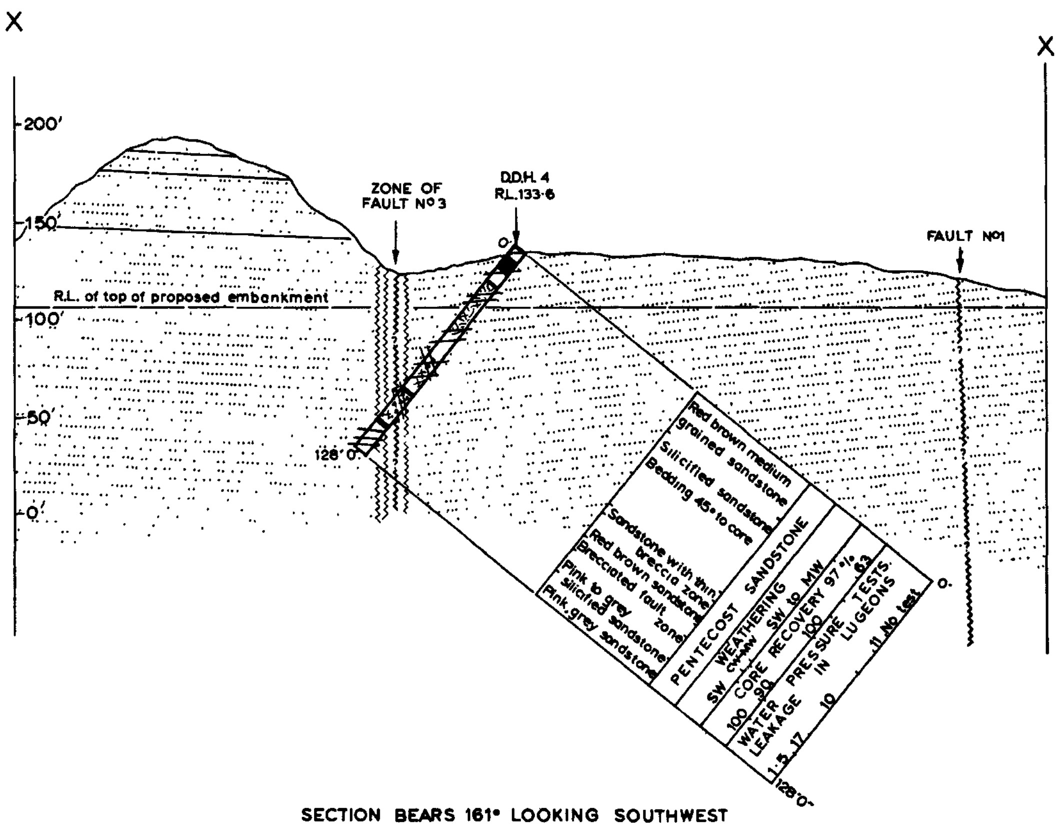
MOOCHALABRA CREEK DAM SITE GEOLOGICAL CROSS SECTIONS THROUGH DRILL HOLES Nº 1, 2, 3, 4, & 5A

To accompany report by J.D.Wyatt, 1966



LOCALITY MAP
N
WEST ARM CAMBRIDGE GULF
Wyndham
WEDGE HILLS
THE BASTION RANGE
Great Northern Highway
LEAKE HILLS
King River
Dam site
Moochalabra Ck.
The Diggers Rest Pumping station
4 3 2 1 0 4 miles
REFERENCE
QUATERNARY
ALLUVIUM — Coastal silt, mud, evaporite
ALLUVIUM — Boulders, cobbles, sand
SCREE — Scree and soil cover
PROTEROZOIC
BASTION GROUP MENDENA FORMATION — Green and purple siltstone, sandstone interbeds
KIMBERLEY GROUP PENTECOST SANDSTONE — Blocky medium-grained quartz sandstone and siltstone
ROADS AND ACCESS TRACKS
VERTICAL DRILLHOLE
INCLINED DRILLHOLE
COSTEAN
GEOLOGICAL OUTCROP BOUNDARY
QUARTZ VEIN
SHEAR
FAULT
FAULT (INFERRED)
STRIKE AND DIP OF BEDDING
STRIKE AND DIP OF CURRENT BEDDING
STRIKE AND DIP OF JOINTS
SLICKENSIDE WITH PLUNGE DIRECTION
DRAGFOLD WITH PLUNGE DIRECTION
AXIS OF ANTICLINE WITH PLUNGE DIRECTION
BRECCIA
SURVEY STATIONS — G.S.W.A and P.W.D
PWD PEGGED TRIAL CENTRELINE
ALTERNATIVE CENTRELINES
DIAMOND DRILLHOLE SECTION LINE
SCALE IN FEET
100 0 100 200 300 400 feet
GEOLOGICAL SURVEY OF WESTERN AUSTRALIA
MOOCHALABRA CREEK DAM SITE
GEOLOGICAL MAP
To accompany report by J D Wyatt 1966
N
WYNDHAM
STATION TRACK
PUMPING
RIVER
KING
FAULT No 1
FAULT No 2
FAULT No 3
MINOR CROSS WARP
LOCAL ANTICLINAL AXIS
BULLDOZED TRACK FOR DRILL ACCESS
MOOCHALABRA CREEK
ALLUVIAL SAND DEPOSITS
CENTRELINE SITE 2
CENTRELINE SITE 3
TRIAL CENTRELINE Site 1
BULLDOZED TRACK SECTION LINE
BULLDOZED TRACK
QUARRY SITE AREA
Pool
STEEP CLIFF
VERTICAL CLIFF
DDH No 1
R.L. 40' approx
DDH No 2
DDH No 3
DDH No 4
DDH No 5
DDH No 5A
G2
G3
G5
G6
G7
G8
G9
B2
B3
X
Y





SECTION BEARS 161° LOOKING SOUTHWEST

NOTES

1. Description of material in logs of drill hole refer only to core recovered
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3. Angle of bedding and joints is the angle between joint planes and plane perpendicular to the axis of the drillhole
4. Water pressure test losses are expressed in lugeons
   One lugeon is equal to a water loss of 1 litre per minute per metre of hole at 10 times atmospheric pressure

WEATHERING

F = Fresh rock
LSJ = Limonite stained joints
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REFERENCE

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- Brecciated sandstone
- ·B2. P.W.D. survey peg
- Trace of bedding
- Water table
- Fault zone
- W.L. Water level
- R.L. Reduced level

50 0 50 100 150 200 250 feet
NATURAL SCALE OF FEET

GEOLOGICAL SURVEY OF WESTERN AUSTRALIA

MOOCHALABRA CREEK DAM SITE GEOLOGICAL CROSS SECTIONS THROUGH DRILL HOLES No 1, 2, 3, 4, & 5A

To accompany report by J.D.Wyatt, 1966

9640

Between 100 feet and 150 feet, tests were made at regular 10 or 20 feet intervals and with the pump on maximum output and water pressures of between 20 to 50 pounds per square inch, the losses were as high as 40 lugeons.

From 150 feet to 170 feet, the water losses dropped to 25 lugeons and from 170 feet to the end of the hole the losses dropped to a minimum of 2 lugeons.

The hole was surveyed for dip at 130 feet and 220 feet, and these results showed a flattening of about 1° for every 100 feet of drilling.

SITE APPRAISAL

DAM SITE

The geological features which are considered disadvantageous at the proposed trial centre line are as follows:

1. The presence of two faults upstream from the proposed centre line, one of which (Fault No. 3) may form a leakage path through the topographic saddle separating Moochalabra Creek from the King River.

2. The open nature of the jointing and bedding planes, which in places has caused the deep weathering of the sandstone and in turn has been followed by the erosional removal of broken rock as far back as 20 feet into the cliff face.

The permeability of the sandstone by way of these fractures will make it difficult to achieve a watertight bond between the abutment and the impervious clay core.

3. The steepness and height of the cliff face forming the right abutment. As the top of the proposed dam is expected to be around RL 106 feet and as the cliff rises to RL 200, this means that a steep cliff face will rise about 100 feet above the embankment. With an unknown thickness of loose scree on the upper slopes, this would constitute a considerable hazard during construction.

Two other sites, Nos. 2 and 3 (Plate 18), were selected as possible alternatives. Neither has been investigated by drilling and it is likely that the foundation conditions will be very similar to site No. 1.

One advantage of site No. 2, is that it is located upstream from the original trial centre line and will therefore avoid the two faults on the right bank of Moochalabra Creek. Site No. 3, located downstream from site No. 1 will not have a steep cliff face on the right abutment.

SPILLWAY SITE

A site for the proposed spillway has been tentatively chosen on the spur forming part of the left bank of Moochalabra Creek. The same location with minor alterations as to direction and depth of the cut, will be common to all three proposed dam sites.

Because of the gentle slope (6°) of this side of the river valley, and the presence of several broad bedding terraces, excavation of the proposed spillway channel will be simplified.

The rock type is jointed sandstone, with fine-grained silty sandstone interbeds. Drilling indicates that the upper 10 feet of rock will contain several weathered horizons. This material will either have to be removed during construction or protected from future erosion when the spillway is in use.

CONSTRUCTION MATERIALS

ROCKFILL

Abundant rockfill will be available from the Pentecost Sandstone and a quarry site has been selected in this rock unit on the left bank of the river, centred on 350N 1400E (Plate 18).

The site consists of a number of river terraces, formed by erosion of flat bedding plane surfaces. The lowest terrace is about 15 to 20 feet above the bed of Moochalabra Creek, and the next about 20 feet higher.

Excavation of the rock, from Moochalabra Creek south, will enable advantage to be taken of the natural face formed along the left bank of the river.

As quarrying continues to the second terrace a 40-foot high working face will be formed. If the dam is built in one year, no problems will arise when the river is in flood, sometime between December and April.

Some scree occurs as talus slopes between the terraces. The size of the blocks is between 12 inches x 12 inches x 18 inches up to 72 inches x 30 inches x 18 inches.

FILTER ZONE MATERIAL

Sufficient suitable filter zone material will be available from the bed of Moochalabra Creek, although it will need washing and screening.

IMPERVIOUS BORROW

The search for impervious clay borrow was concentrated along both sides of the access track between the dam site and King River Pumping Station. Elsewhere, random samples were taken of likely material for distances of up to 16 miles from the dam site.

Little of the material sampled by the auger drilling was suitable, most of the samples being either silty sand or sticky black mud.

One area, west of the King River Pumping Station was drilled late in 1966. Laboratory tests completed to date suggest that this area will be a source of suitable impervious borrow.

CONCLUSIONS

The rock types at the proposed dam site are alluvium in the river channel overlying a sandstone with silty interbeds and a silty-sandstone with shale interbeds. The beds dip generally west at between 5° and 15° and strike N25°E. Crossbedding and ripple marking are common.

There are two dominant, steeply dipping joint sets striking north and east.

Three large faults were mapped, one of which, Fault No. 3, is known to be important as a possible leakage path from the reservoir.

Folding is restricted to one northeasterly trending anticline centred on 400N 050W, and some small flexures in the sandstones cropping out in the steep cliffs on the right bank of the river.

Diamond drilling was restricted to give holes put down along a proposed trial centre line, and drilling revealed that:

1. Frequent jointing and major open bedding planes are responsible for high water losses of up to 40 lugeons being recorded during water pressure testing.

2. The sandstone is in places deeply weathered usually along the bedding, down to at least 10 or 15 feet below the ground surface. This weathering is selective and may only involve one or two horizons of sandstone.

One trial centre line for the proposed dam was investigated by detailed mapping and diamond drilling, and the main disadvantages of this site appear to be:

1. the excessive permeability of the abutments, especially the right abutment

2. the steep cliff face forming the right abutment

3. the presence of large faults upstream from the proposed dam site which may affect the water tightness of the proposed reservoir.

Two other tentative sites were selected, upstream and downstream from the original trial centre line B_1-B_3.

The possible advantage of site No. 2 is its position upstream from the two faults, whilst the advantage of site No. 3 is that it does not have a steep cliff face forming the right abutment. Neither of these two alternatives appears to have any advantages in the foundations.

REFERENCES

Gordon, F. R., 1966, Geological reconnaissance at Moochalabra Creek dam site: West. Australia Geol. Survey Rec. 1966/8 (unpublished).

Plumb, K. A., and Veevers, J. J., 1965, Explanatory notes on the Cambridge Gulf 1:250,000 Geological Sheet SD/52-14, Western Australia: Australia Bur. Mineral Resources Rec. 1965/174 (unpublished).

HYDROGEOLOGICAL FEATURES OF THE GASCOYNE RIVER, WEST OF THE KENNEDY RANGE

by J. L. Baxter

ABSTRACT

A reconnaissance of the Gascoyne River, to determine the feasibility of transporting water in the channel from the proposed dam site at Kennedy Range to Carnarvon, has shown that there are three main areas from which water will be lost. These are the Birdrong Formation and two abandoned channels of the river.

INTRODUCTION

A dam to supply the Carnarvon irrigation area is proposed for a site on the Gascoyne River in the southern end of the Kennedy Range, 92 miles east of Carnarvon.

The present water supply for Carnarvon is obtained from the alluvial deposits of the river, but the supply of water is limited. Recharge of these sands is dependent on flows of the river, and these flows are intermittent and sometimes quite small. The amount of water pumped from the river in 1964-65 was 1,004 million gallons and in 1965-66 was 1,321 million gallons.

To avoid the expense of a pipeline from the dam to Carnarvon it has been proposed by the Public Works Department that the water be transported in the existing river channel by releases to keep the river sands saturated. A reconnaissance survey was carried out as part of the initial investigation to determine the feasibility of this scheme. A geological sketch map of the area is shown on Plate 20.

PHYSIOGRAPHY AND CLIMATE

The Gascoyne River flows west through the southern end of the Kennedy Range and across broad flood plains to Rocky Pool. Although the main channel continues west, there are numerous distributary streams forming anabranches which may flow at times of river flooding. The Gascoyne River is mature throughout its course west of the Kennedy Range. The river to Fishy Pool, 17 miles west of the dam site, has a gradient of approximately 1 in 880 and flows over basin sediments. It is up to half a mile wide and in places is braided. From Fishy Pool to Rocky Pool the river flows across old flood plains, where the channel is confined between low banks and has a gradient of approximately 1 in 1,000. From Rocky Pool to Carnarvon the river flows through a recent delta in which the gradient is approximately 1 in 1,800.

There are six physiographic subdivisions through which the river flows.

The *Kennedy Range*, the southern end of which has been breached by the river, forms the abutments for the proposed dam site and rises to about 500 feet above the surrounding plain.

The *Mooka surface*, a billy surface about 2 miles wide, is formed along the western margin of the Kennedy Range. It supports little vegetation.

Low rises occur as rocky knolls in the sand dunes and deltaic deposits. There is a line of these ridges northeast of Rocky Pool.

The *sand dunes* cover an area between the Mooka surface and the old river plain. The dunes are between 30 and 80 feet high.

The *old river plain* extends northwest from Fishy Pool and extends southwest to the coast.

It is a flat area with sand rises up to 15 feet high. The area appears to be an old delta of the Gascoyne River.

The *river delta* extends from Rocky Pool to the coast. The dissection of the unconsolidated flood plain deposits by the anabranches is typical of such deltaic areas.

The average rainfall over the Gascoyne River drainage area is 7 inches, the average evaporation is 99 inches. The average maximum temperature in summer is 101°F and the minimum is 71°F. The average maximum temperature in winter is 72°F and the minimum is 46°F.

HYDROLOGICAL AREAS

There are three areas of importance in the hydrology of the Gascoyne River west of the Kennedy Range : the Cretaceous sequence which crops out to a point 17 miles downstream from the proposed dam site ; the old river plain and river delta physiographic areas of the Gascoyne River which are developed west of the Cretaceous sequence and extend to the coast ; and the sand dune unit which lies north and south of the river between the Cretaceous sequence and the river delta.

The Cretaceous sequence

The Cretaceous sequence is composed of a sandstone, shale, and radiolarite. The sandstone is the Birdrong Formation which is the best aquifer in the Carnarvon Basin. It must be considered an important intake source where it crops out in the bed of the Gascoyne River.

The Windalia Radiolarite commonly has a siliceous capping of either billy or opaline material. This surface is usually fractured. The unit is only slightly porous.

The shale, which does not crop out in the bed of the river, is approximately 30 feet thick and weathers to a clay. This unit is relatively impermeable.

The Birdrong Formation crops out from about 3 miles downstream of the proposed dam site to Fishy Pool, a distance of 14 miles. The sandstone is extremely porous and pools form over this unit only where there is a clay layer in the river bed. At Carnarvon the Birdrong Formation produces artesian water from a depth of 1,300 to 1,500 feet.

The salinity of the water in the sub-artesian Highway Bore, which draws from the top of the Birdrong Formation, is 4,000 ppm. The salinity of the water recovered from Brickhouse 4 artesian bore at a depth of 1,500 feet is 3,245 ppm.

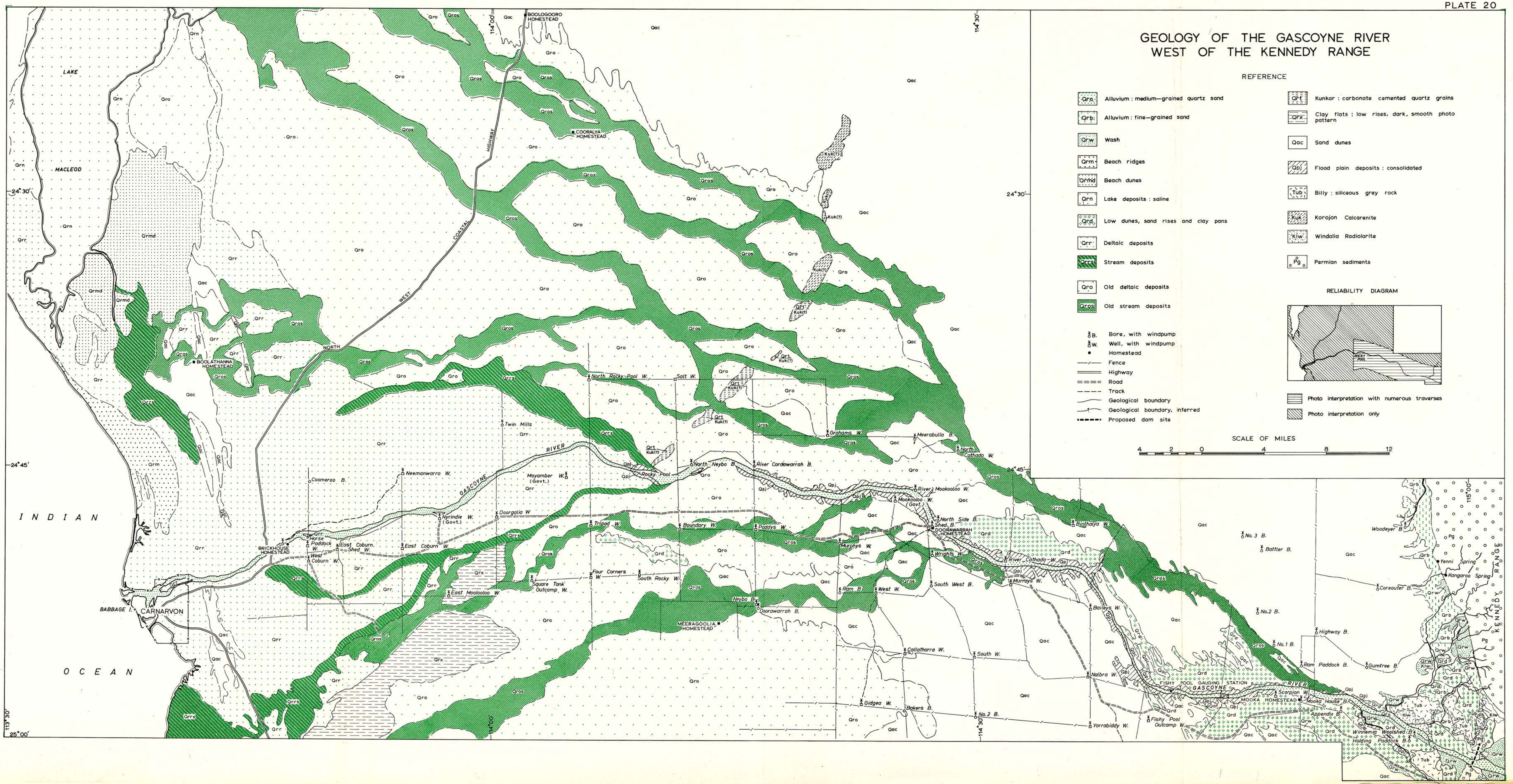
The old river plain and river delta

The old river plain and delta of the Gascoyne River extend from Fishy Pool, 17 miles west of the proposed dam site, to the coast. They can be divided into three distinct groups.

The *present river channel* contains sands of variable thickness acting as reservoirs for water. The salinity of the water is variable from 400 ppm to 2,000 ppm, and all the stations situated on the river use either a river well or a spear to obtain water for domestic purposes. At Carnarvon the water in the river sands is used to irrigate the broad-acre crops grown there.

The *old river channels* are now marked by claypans and small sand rises. The old channels leave the river at Fishy Pool, Doorawarrah, and Rocky Pool. The channel north of Fishy Pool contains a good supply of stock quality water with salinity ranging between 1,800 ppm and 5,000 ppm. This channel is being tapped by at least seven bores. The channel south from Doorawarrah Homestead contains an almost unlimited supply of water with 400 to 3,000 ppm salinity. The water levels in this channel indicate that there is flow away from the river at a gradient of approximately 1 in 900. The depth to the old river sands is about 60 feet. The channels north and south of Rocky Pool contain an unlimited supply of highly saline water.

The *flood plains* between the old channels of the Gascoyne River consist of partly consolidated deltaic sediments. The water in these deposits is more saline than that obtained from the old channels. The salinities range between 1,500 ppm and 7,000 ppm, and generally the supply is poorer.


GEOLOGY OF THE GASCOYNE RIVER
WEST OF THE KENNEDY RANGE
REFERENCE
Qra Alluvium: medium-grained quartz sand
Qrb Alluvium: fine-grained sand
Qrw Wash
Qrm Beach ridges
Qrmd Beach dunes
Qrn Lake deposits: saline
Qrd Low dunes, sand rises and clay pans
Qrr Deltaic deposits
Qrrs Stream deposits
Qro Old deltaic deposits
Qros Old stream deposits
Qrt Kunkar: carbonate cemented quartz grains
Qrx Clay flats: low rises, dark, smooth photo pattern
Qac Sand dunes
Qpj Flood plain deposits: consolidated
Tub Billy: siliceous grey rock
Kuk Korojon Calcarenite
Kiw Windalia Radiolarite
Pg Permian sediments
B. Bore, with windpump
W. Well, with windpump
Homestead
Fence
Highway
Road
Track
Geological boundary
Geological boundary, inferred
Proposed dam site
RELIABILITY DIAGRAM
ROCKY POOL
Photo interpretation with numerous traverses
Photo interpretation only
SCALE OF MILES
4 2 0 4 8 12
INDIAN
OCEAN
LAKE
MACLEOD
CARNARVON
BABBAGE I.
GASCOYNE
RIVER
NORTH WEST COASTAL HIGHWAY
KENNEDY RANGE
BOOLOGOORO HOMESTEAD
COORALYA HOMESTEAD
BOOLATHANNA HOMESTEAD
BRICKHOUSE HOMESTEAD
MEERAGOOLIA HOMESTEAD
DOORAWARRAH HOMESTEAD
MOOKA HOMESTEAD
FISHY POOL GAUGING STATION
Rocky Pool
24°30'
24°45'
25°00'
113°30'
114°00'
114°30'
115°00'

The sand dunes

The sand dunes cover an area which is not affected by the river. The country beneath the dunes contains only small quantities of potable water. The dunes themselves contain small supplies of water of good quality, but these are insufficient to meet stock requirements.

APPRAISAL OF WATER LOSS

The two main areas of intake into which water will be lost from the river are the Birdrong Formation and the old river channels. The Birdrong Formation will take a considerable quantity of water along the 14-mile stretch in which it is exposed to the Gascoyne River bed. The old river channels which leave the river from Fishy Pool and Rocky Pool will take a certain amount of water, but it is expected that most will be taken by the channel which leaves the river east of Doorawarrah.

RECOMMENDATIONS AND CONCLUSIONS

1. The course of the Gascoyne River west of the Kennedy Range has many areas from which water would be lost while flowing from the dam site to Carnarvon.

2. These areas must be tested by measurements over a considerable period of time and during all stages of the river flow from drought to flood conditions. Tests will include flow testing, measurement of the variation of water level and salinity in the bores at present in the old channels, and drilling in the Birdrong Formation at the intake areas along the channel.

3. The potential of the old river channels as sources for water supplies to stations is high. These channels contain large quantities of water suitable for stock and some water suitable for domestic purposes.

4. The possibility of a low head dam at Rocky Pool, as originally proposed by the Public Works Department, should be reviewed. The possibility of discharging water from the dam into the channels to the north and south from Rocky Pool would provide some measure of flood control on the river, and possibly extend the irrigation area along these channels. The dam site at Rocky Pool should provide sufficient water for the immediate projected needs of the Carnarvon irrigation area.

THE SEARCH FOR OIL IN WESTERN AUSTRALIA IN 1966

by P. E. Playford and G. H. Low

INTRODUCTION

The principal development in the search for oil during 1966 was the announcement by West Australian Petroleum Pty. Ltd. that Barrow Island would be developed as Western Australia's first commercial oilfield, and that production would commence during 1967. This success has come to the company after 15 years of continuous exploration, and more than 60 years after the first exploratory well for oil was drilled in the State.

The amount of drilling carried out in 1966 was similar to that in 1965. A total of 25 test wells, 4 stratigraphic wells, and 5 structure wells were drilled during the year, and another test well was still drilling on December 31st. In addition 5 development wells were put down on Barrow Island and these were awaiting testing at the end of the year. Of the test wells, 11 were completed as potential producers : 5 oil wells, 1 oil and gas well, 3 gas wells, and 2 gas and condensate wells. Two more were suspended pending completion as producing wells. By comparison, during 1965 there were 26 test wells and 10 stratigraphic wells completed, and of the test wells 20 were potential producers.

Geophysical exploration declined during 1966 compared with the previous year. Seismic operations decreased from 93 party months in 1965 to 72 in 1966, and gravity surveys fell from 14 party months to 5½. Aeromagnetic surveys totalling some 2,700 line miles were flown in 1966 compared with 44,000 line miles the previous year. Field geological surveys amounted to 9 geologist months in 1966 compared with 16 in 1965.

OIL HOLDINGS

The positions of permits to explore and licenses to prospect in Western Australia at the end of 1966 are shown on Plate 21. Details of each concession current at the end of the year are as follows :

OIL HOLDINGS IN WESTERN AUSTRALIA ON 31st DECEMBER, 1966

Permits to Explore

No.	Name of Holder	Area in Square Miles	Date of Expiry of Current Tenure
27H	West Australian Petroleum Pty. Ltd.	34,650	31/12/66 (renewal applied for)
28H	do. do. do.	30,750	do.
30H	do. do. do.	140,200	do.
106H	Westralian Oil Limited	11,800	28/9/67
127H	Alliance Oil Development Australia N.L.	13,800	28/3/67
134H	Exoil Pty. Ltd. and Hunt Petroleum Corporation	12,600	31/3/67
135H	do. do. do.	12,600	31/3/67
136H	do. do. do.	12,450	31/3/67
151H	Beach-General Exploration Pty. Ltd.	14,200	7/2/68
152H	do. do. do.	11,650	7/2/68
153H	do. do. do.	13,050	7/2/68
172H	Alliance Petroleum Australia N.L.	6,150	30/3/67
173H	do. do.	12,250	30/3/67
174H	do. do.	6,100	30/3/67
175H	do. do.	6,050	30/3/67
177H	do. do.	6,050	30/3/67
193H	Hawkstone Oil Co. Ltd., BP Petroleum Development Australia Pty. Ltd.	2,750	5/2/67
205H	Alliance Petroleum Australia N.L.	16,700	17/9/67
218H	Woodside (Lakes Entrance) Oil Co. N.L., B.O.C. of Aust. Ltd., Shell Development (Aust.) Pty. Ltd.	104,000	20/6/67
217H	West Australian Petroleum Pty. Ltd.	17,600	30/5/67
221H	Australian Aquitaine Petroleum Pty. Limited, Arco. Ltd.	44,000	28/7/67
225H	West Australian Petroleum Pty. Limited	8,000	20/7/67
226H	do. do. do.	34,700	6/4/67
227H	do. do. do.	11,400	6/4/67
228H	do. do. do.	2,900	13/5/67
232H	Victorian Oil No Liability	3,000	20/6/67
233H	West Australian Petroleum Pty. Ltd....	6,800	10/2/67
235H	Canadian Superior Oil (Aust.) Pty. Ltd.	19,400	21/1/67
236H	Abrolhos Oil No Liability, BP Petroleum Development Australia Pty. Ltd.	2,600	3/2/67
238H	B.O.C. of Australia Ltd., Shell Development (Aust.) Pty. Ltd., Woodside (Lakes Entrance) Oil Coy. N.L.	1,260	9/1/68
240H	Coastal Petroleum N.L.	11,850	14/6/68
241H	do. do.	11,850	14/6/68
242H	do. do.	11,850	14/6/68
243H	do. do.	11,850	14/6/68
251H	West Australian Petroleum Pty. Ltd....	4,228	29/6/68
253H	Westralian Oil Limited	5,200	28/12/68
254H	Tenneco Australia Inc.	12,100	Appl. pending
256H	Continental Oil Company of Australia Ltd., Australian Sun Oil Company	12,850	do.
257H	do. do. do.	12,850	do.

Licenses to Prospect

No.	Name of Holder			Area in Square Miles	Date of Expiry of Current Tenure
96H	West Australian Petroleum Pty. Limited			100.00	18/3/67
97H	do.	do.	do.	191.396	26/7/67
99H	do.	do.	do.	190.458	4/12/67
101H	do.	do.	do.	193.62	17/12/67
102H	do.	do.	do.	195.551	13/1/67
103H	do.	do.	do.	200.00	20/5/67
104H	do.	do.	do.	197.867	7/6/67
105H	do.	do.	do.	196.032	14/8/67
106H	do.	do.	do.	200.00	11/9/67
107H	do.	do.	do.	200.00	25/2/67
108H	do.	do.	do.	200 (excluding Lyndon Loc. 42)	17/1/67
109H	do.	do.	do.	200.00	22/2/67
111H	do.	do.	do.	150.00	4/6/67
113H	do.	do.	do.	200.00	10/5/66 (to be converted to leases)
114H	Alliance Oil Development Aust. N.L.			67.00	27/10/67
115H	West Australian Petroleum Pty. Limited			200.00	5/5/67
117H	do.	do.	do.	200.00	10/9/67
118H	do.	do.	do.	117.687	29/9/67
119H	do.	do.	do.	109.032	12/1/67
120H	Westralian Oil Limited			195.984	30/11/67
121H	Associated Freney Oil Fields N.L.			120.00	11/7/67
122H	do.	do.	do.	113.418	11/7/67
123H	do.	do.	do.	113.232	11/7/67
124H	do.	do.	do.	112.528	20/4/67
125H	do.	do.	do.	112.477	20/4/67
126H	West Australian Petroleum Pty. Limited			200.00	8/2/67
127H	do.	do.	do.	200.00	17/1/67
128H	do.	do.	do.	182.00	8/3/67
129H	do.	do.	do.	200.00	8/3/67
130H	do.	do.	do.	189.929	28/3/67
132H	do.	do.	do.	200.001	13/5/67
133H	do.	do.	do.	200.001	13/5/67
135H	do.	do.	do.	106.197	17/5/67
136H	do.	do.	do.	190.765	17/5/67
137H	do.	do.	do.	8.830	17/5/67
138H	do.	do.	do.	196.224	17/5/67
139H	do.	do.	do.	189.684	17/5/67
140H	do.	do.	do.	198.750	17/5/67
141H	do.	do.	do.	188.941	17/5/67
142H	do.	do.	do.	193.350	17/5/67
143H	do.	do.	do.	198.133	17/5/67
144H	do.	do.	do.	193.104	17/5/67
145H	do.	do.	do.	187.411	17/5/67
146H	do.	do.	do.	187.032	17/5/67
147H	do.	do.	do.	188.958	17/5/67
148H	do.	do.	do.	200.00	9/6/67
149H	do.	do.	do.	200.00	14/7/67
150H	do.	do.	do.	200.00	18/10/67
151H	do.	do.	do.	194.367	5/7/67
152H	do.	do.	do.	192.00	18/10/67
153H	do.	do.	do.	196.00	18/10/67
154H	Beach-General Exploration Pty. Ltd.			160.20	13/12/67
155H	West Australian Petroleum Pty. Ltd.			193.75	18/10/67
156H	do.	do.	do.	189.269	Appl. pending
157H	do.	do.	do.	188.973	15/2/68
158H	do.	do.	do.	196.00	20/3/68
159H	do.	do.	do.	196.00	20/3/68
160H	do.	do.	do.	195.871	20/3/68
161H	do.	do.	do.	196.129	20/3/68
162H	do.	do.	do.	196.00	20/3/68
163H	do.	do.	do.	200.00	20/3/68
164H	do.	do.	do.	199.997	20/3/68
165H	do.	do.	do.	200.00	20/3/68
166H	do.	do.	do.	133.841	13/3/68
167H	do.	do.	do.	160.520	13/3/68
168H	do.	do.	do.	186.473	13/3/68
169H	do.	do.	do.	200.00	20/3/68
171H	do.	do.	do.	190 provisional	14/4/68
172H	do.	do.	do.	199.697	21/6/68
173H	do.	do.	do.	190 provisional	10/8/68
174H	do.	do.	do.	190 provisional	29/7/68
175H	do.	do.	do.	200.00	11/8/68
176H	do.	do.	do.	188.968	27/9/68
177H	do.	do.	do.	200 provisional	20/12/68
178H	do.	do.	do.	200 provisional	Appl. pending
179H	do.	do.	do.	197 provisional	Appl. pending
180H	do.	do.	do.	195 provisional	Appl. pending
181H	do.	do.	do.	200.00	Appl. pending
182H	do.	do.	do.	200.00	Appl. pending

DRILLING

The positions of wells drilled for petroleum exploration in Western Australia to the end of 1966 are shown on Plates 22 to 25. Drilling was carried out during the year in the following permits :

PERMIT TO EXPLORE 27H

Permit to Explore 27H is held by West Australian Petroleum Pty. Ltd. and covers part of the Perth Basin. The company completed 6 test wells (Dongara Nos. 1-3, Gingin No. 2, Mt. Adams No. 1, and Sue No. 1) during the year, and another (Erregulla No. 1) was still being tested on 31st December. A single stratigraphic well (Preston No. 1) was drilled during 1965.

The three wells at Dongara were all completed as potential gas producers. Dongara No. 1 was located near the crest of an anticlinal structure delineated by seismic methods. The gas reservoir in this well is the ' Basal Triassic Sandstone', which also contained oil and gas at Yardarino. It underlies the Kockatea Shale and was encountered in Dongara No. 1 between 5,482 feet and 5,516 feet. Testing of this unit yielded dry gas flows of up to 10·3 mmcf/day (on a ½-inch choke).

Dongara No. 2 was drilled three-quarters of a mile west-northwest of No. 1, and was also completed in the ' Basal Triassic Sandstone '. Testing yielded up to 9·1 mmcf/day of dry gas (on a ⅜-inch choke). The third well was sited three-quarters of a mile east-southeast of No. 1. It yielded flows of 3·24 mmcf/day (on a ¼-inch choke) from the ' Basal Triassic Sandstone', and 1·95 mmcf/day (on a ¼-inch choke) from the Irwin River Coal Measures, in which formation the well was completed as a potential producer.

There has been no further drilling at Dongara since the No. 3 well was completed in September 1966. None of the wells have penetrated the petroleum water interface, and it appears that a significant gas field is present. It is possible that an oil column is developed on the flanks of the structure, though oil was not recovered in any of the three wells drilled to date.

Gingin No. 1 was completed as a gas and condensate well in 1965, production being obtained from the Lower Jurassic Cockleshell Gully Formation. Gingin No. 2 was then drilled 2 miles south and 1 mile east of No. 1 to determine the extent of the field. The well was completed as a potential producing gas and condensate well in January 1966. An initial flow of 3·92 mmcf/day of gas with 270 bbl/day of condensate was obtained from the interval 13,962 to 14,704 feet, but this fell rapidly with prolonged testing. Production testing of Gingin No. 1 continued during the year, but no decision has been made on the possible economic development of the field.

A small amount of oil was recovered from the Erregulla No. 1 well in the Cockleshell Gully Formation. Swabbing of the interval 10,413 to 10,435 feet for 3½ hours yielded 22½ barrels of oil. Testing of the well was still in progress at the end of the year.

Further details of the wells drilled in Permit 27H during the year are as follows :

Dongara No. 1

Type: Test well.
License to Prospect: 111H.
Latitude and Longitude: 29° 15′ 07″ S., 114° 59′ 14″ E.
Elevation: Ground level 148 feet, derrick floor 161 feet.
Commenced: 30th March, 1966.
Rig released: 2nd July, 1966.
Total depth: 7,080 feet.
Bottomed in: Lower Permian.
Status: Gas well, completed over the interval 5,482 to 5,495 feet in the ' Basal Triassic Sandstone'. Production of 10·3 mmcf/day on a ½-inch choke, 3·14 mmcf/day on a ¼-inch choke.

Dongara No. 2

Type: Test well.
License to Prospect: 111H.
Latitude and Longitude: 29° 14′ 54″ S., 114° 58′ 29″ E.
Elevation: Ground level 74 feet, rotary table 87 feet.
Commenced: 31st July, 1966.
Rig released: 12th August, 1966.
Total depth: 5,725 feet.
Bottomed in: Lower Permian.
Status: Gas well, completed over the interval 5,515 to 5,527 feet in the ' Basal Triassic Sandstone'. Production of 9·1 mmcf/day on a ⅜-inch choke, 2·8 mmcf/day on a ¼-inch choke.

Dongara No. 3
Type: Test well.
License to Prospect: 111H.
Latitude and Longitude: 29° 15′ 28″ S., 114° 59′ 59″ E.
Elevation: Ground level 91 feet, rotary table 104 feet.
Commenced: 2nd September, 1966.
Rig released: 18th September, 1966.
Total depth: 5,822 feet.
Bottomed in: Lower Permian.
Status: Gas well, completed over the interval 5,490 to 5,502 feet in the Irwin River Coal Measures. Production of 1·95 mmcf/day on a ½ - inch choke.

Erregulla No. 1
Type: Test well.
License to Prospect: 175H.
Latitude and Longitude: 29° 22′ 28″ S., 115° 23′ 45″ E.
Elevation: Ground level 763 feet, rotary table 779 feet.
Commenced: 3rd September, 1966.
Total depth: 13,925 feet.
Status: Testing on 31st December. 22½ barrels of oil obtained in 3½ hours by swabbing the interval 10,413 to 10,435 feet in the Cockleshell Gully Formation.

Gingin No. 2
Type: Test well.
License to Prospect: 115H.
Latitude and Longitude: 31° 10′ 18″ S., 115° 50′ 35″ E.
Elevation: Ground level 856 feet, rotary table 872 feet.
Commenced: 25th July, 1965.
Rig released: 18th January, 1966.
Total depth: 14,704 feet.
Bottomed in: Lower Jurassic.
Status: Gas and condensate well, completed over the intervals 14,011 to 14,110, 14,150 to 14,210, 14,270 to 14,380, and 14,540 to 14,640 feet in the Cockleshell Gully Formation. Testing of the interval 13,962 to 14,704 feet produced up to 270 barrels/day of oil and 3·92 mmcf/day of gas.

Mt. Adams No. 1
Type: Test well.
License to Prospect: 171H.
Latitude and Longitude: 29° 24′ 25″ S., 115° 10′ 00″ E.
Elevation: Ground level 282 feet, rotary table 298 feet.
Commenced: 26th March, 1966.
Rig released: 24th May, 1966.
Total depth: 12,438 feet.
Bottomed in: Lower Permian.
Status: Dry, plugged, and abandoned.

Preston No. 1
Type: Stratigraphic well.
Latitude and Longitude: 32° 56′ 53″ S., 115° 42′ 33″ E.
Elevation: Ground level 20 feet, rotary table 25 feet.
Commenced: 26th August, 1966.
Rig released: 18th September, 1966.
Total depth: 2,511 feet.
Bottomed in: Lower Jurassic.
Status: Dry, plugged, and abandoned.

Sue No. 1
Type: Test well.
License to Prospect: 152H.
Latitude and Longitude: 34° 03′ 54″ S., 115° 19′ 04″ E.
Elevation: Ground level 269 feet, rotary table 282 feet.
Commenced: 31st January, 1966.
Rig released: 8th March, 1966.
Total depth: 10,097 feet.
Bottomed in: Precambrian.
Status: Dry, plugged, and abandoned.

PERMIT TO EXPLORE 28H

Permit to Explore 28H is held by West Australian Petroleum Pty. Ltd., and covers part of the Carnarvon Basin. The company completed 2 test wells (Glenroy No. 1 and Onslow No. 1), 5 structure wells (Merlinleigh Nos. 1-5), and 2 stratigraphic wells (Long Island No. 1 and Tortoise Island No. 1) on this permit in 1966, and another test well, Kennedy Range No. 1, was still drilling at the end of the year. Onslow No. 1 yielded a small flow of gas from a Lower Cretaceous sand, but was abandoned. The other wells were dry. Details of the wells are as follows:

Glenroy No. 1
Type: Test well.
License to Prospect: 174H
Latitude and Longitude: 21° 49′ 05″ S., 114° 52′ 28″ E.
Elevation: Ground level 10 feet, rotary table 15 feet.
Commenced: 19th October, 1966.
Rig released: 29th October, 1966.
Total depth: 2,127 feet.
Bottomed in: Lower Cretaceous.
Status: Dry, plugged, and abandoned.

Kennedy Range No. 1
Type: Test well.
License to Prospect: 153H.
Latitude and Longitude: 24° 29′ 45″ S., 114° 59′ 27″ E.
Elevation: Ground level 968 feet, kelly bushing 980 feet.
Commenced: 1st December, 1966.
Status: Drilling ahead at 5,694 feet on 31st December, 1966.

Long Island No. 1
Type: Stratigraphic well.
License to Prospect: 165H.
Latitude and Longitude: 21° 37′ 10″ S., 114° 41′ 10″ E.
Elevation: Ground level 16 feet, rotary table 30 feet.
Commenced: 21st September, 1966.
Rig released: 3rd November, 1966.
Total depth: 7,081 feet.
Bottomed in: Middle Triassic.
Status: Dry, plugged, and abandoned.

Merlinleigh No. 1
Type: Structure well.
Latitude and Longitude: 24° 29′ 48″ S., 114° 59′ 15″ E.
Elevation: Ground level 953 feet, rotary table 958 feet.
Commenced: 18th May, 1966.
Rig released: 26th May, 1966.
Total depth: 1,000 feet.
Bottomed in: Lower Permian.
Status: Dry, plugged, and abandoned.

Merlinleigh No. 2
Type: Structure well.
Latitude and Longitude: 24° 28′ 45″ S., 114° 59′ 27″ E.
Elevation: Ground level 961 feet, rotary table 966 feet.
Commenced: 30th May, 1966.
Rig released: 15th June, 1966.
Total depth: 1,003 feet.
Bottomed in: Lower Permian.
Status: Dry, plugged, and abandoned.

Merlinleigh No. 3
Type: Structure well.
Latitude and Longitude: 24° 29′ 08″ S., 114° 59′ 53″ E.
Elevation: Ground level 964 feet, rotary table 969 feet.
Commenced: 30th June, 1966.
Rig released: 6th July, 1966.
Total depth: 545 feet.
Bottomed in: Lower Permian.
Status: Dry, plugged, and abandoned.

Merlinleigh No. 4
Type: Structure well.
Latitude and Longitude: 24° 29′ 08″ S., 114° 58′ 57″ E.
Elevation: Ground level 950 feet, rotary table 955 feet.
Commenced: 6th July, 1966.
Rig released: 10th July, 1966.
Total depth: 445 feet.
Bottomed in: Lower Permian.
Status: Dry, plugged, and abandoned.

Merlinleigh No. 5

Type: Structure well.
Latitude and Longitude: 24° 28′ 27″ S., 114° 59′ 07″ E.
Elevation: Ground level 952 feet, rotary table 957 feet.
Commenced: 14th July, 1966.
Rig released: 18th July, 1966.
Total depth: 575 feet.
Bottomed in: Lower Permian.
Status: Dry, plugged, and abandoned.

Onslow No. 1

Type: Test well.
License to Prospect: 174H.
Latitude and Longitude: 21° 45′ 56″ S., 114° 52′ 17″ E.
Elevation: Ground level 0 feet, rotary table 16 feet.
Commenced: 1st September, 1966.
Rig released: 14th November 1966.
Total depth: 9,835 feet.
Bottomed in: Permian.
Status: A drill stem test of the interval 1,724 to 1,728 feet in the ' Basal Cretaceous Sandstone ' yielded 100 to 200 mcf/day of gas and 150 to 160 barrels/day of water. Plugged and abandoned.

Tortoise Island No. 1

Type: Stratigraphic.
License to Prospect: 173H.
Latitude and Longitude: 21° 35′ 08″ S., 114° 51′ 11″ E.
Elevation: Ground level 16 feet, rotary table 30 feet.
Commenced: 14th November, 1966.
Rig released: 26th December, 1966.
Total depth: 7,000 feet.
Bottomed in: Jurassic.
Status: Dry, plugged, and abandoned.

PERMIT TO EXPLORE 30H

Permit to Explore 30H covers part of the Canning Basin and is held by West Australian Petroleum Pty. Ltd. The company drilled a single well, Kidson No 1, in the permit area during 1966. Details are as follows:

Kidson No. 1

Type: Test well.
License to Prospect: 155H.
Latitude and Longitude: 22° 37′ 00″ S., 125° 00′ 27″ E.
Elevation: Ground level 1,165 feet, rotary table 1,181 feet.
Commenced: 21st November, 1965.
Rig released: 20th July, 1966.
Total depth: 14,539 feet.
Bottomed in: Lower Ordovician.
Status: Dry, plugged, and abandoned.

PERMIT TO EXPLORE 147H

Permit to Explore 147H was held by Hunt Oil Co. and Placid Oil Co. in the Officer Basin. A single well, Yowalga No. 2, was drilled on this permit during the year. This hole encountered Proterozoic rocks at shallow depth, and as a result the companies decided to withdraw from exploration in this State, and relinquished the concessions they had held. Details of the well are as follows:

Yowalga No. 2

Type: Test well.
License to Prospect: 170H.
Latitude and Longitude: 26° 10′ 12″ S., 125° 58′ 00″ E.
Elevation: Ground level 1,550 feet, kelly bushing 1,563 feet.
Commenced: 1st March, 1966.
Rig released: 24th March, 1966.
Total depth: 3,246 feet.
Bottomed in: Upper Proterozoic.
Status: Dry, plugged, and abandoned.

PERMIT TO EXPLORE 151H

Permit to Explore 151H is held by Beach-General Exploration Pty. Ltd. in the eastern Canning Basin. The permit is farmed out to Australian Aquitaine Petroleum Pty. Ltd., and the company completed one stratigraphic well, Point Moody No. 1, during the year. Details are as follows:

Pt. Moody No. 1

Type: Stratigraphic well.
License to Prospect: 154H
Latitude and Longitude: 21° 15′ 34″ S., 127° 48′ 22″ E.
Elevation: Ground level 1,387 feet, rotary table 1,400 feet.
Commenced: 2nd October, 1965.
Rig released: 14th January, 1966.
Total depth: 8,009 feet.
Bottomed in: Upper Carboniferous.
Status: Minor gas shows. Plugged and abandoned.

PERMIT TO EXPLORE 217H

Permit to Explore 217H covers the northern end of the Carnarvon Basin and is held by West Australian Petroleum Pty. Ltd. The company drilled 10 test wells (Barrow Nos. 19-28) and 5 development wells on Barrow Island during the year. The development wells and Barrow Nos. 27 and 28 were suspended at the end of the year, pending completion as producing wells. Of the others all except Barrow No. 25 (which was dry) were completed as producers.

It was announced in May, 1966, that West Australian Petroleum Pty. Ltd. would proceed with the commercial development of the Barrow Island oilfield. Production would commence in May, 1967 at a rate of about 9,000 barrels per day, and this was expected to rise to about 20,000 barrels per day in two years.

A total of 6 producing reservoirs have now been established on Barrow Island; the Windalia sands at about 2,000 feet (oil and gas), the Neocomian sands at about 5,500 feet (gas and condensate), and four Jurassic sands at about 6,200 feet, 6,600 feet, 6,700 feet, and 6,870 feet respectively (oil and gas). Of these the Windalia is the most extensive, and production will be mainly from this reservoir, although the Jurassic sands will also contribute. The Windalia field covers some 24,700 acres with an average productive sand interval of 44 feet. It is estimated that 240 wells, on 80-acre spacing, will be required to develop this field. The primary recovery percentage from the Windalia sands is expected to be low as they have very low permeabilities, and commonly require fracturing. The company initially estimated that the primary recovery from the Windalia would amount to at least 85,000,000 barrels, but subsequently it was announced that this figure had been increased to 114,000,000 barrels. The company will also experiment with secondary recovery methods to determine whether the economic recovery can be increased.

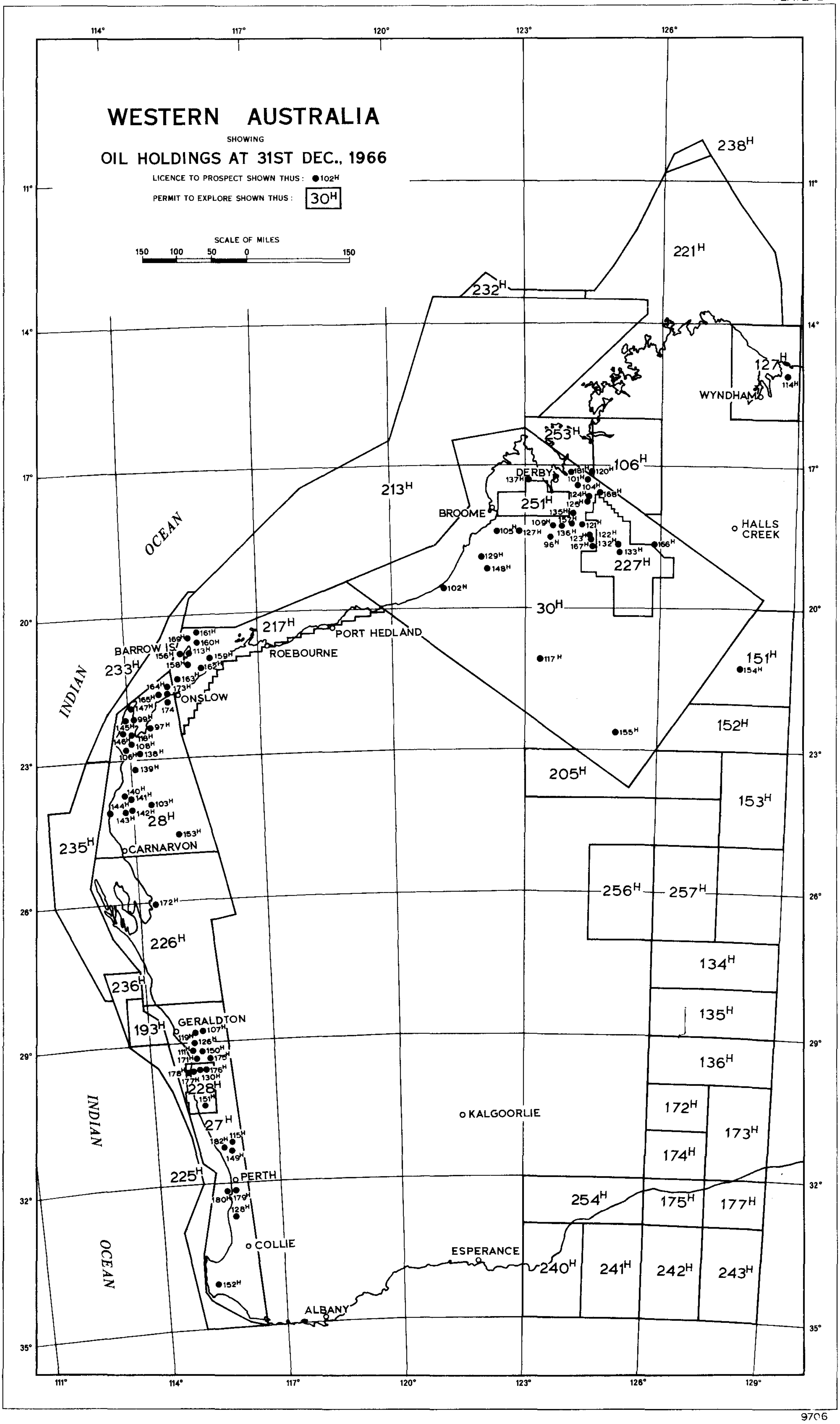
Details of wells drilled during 1966 are as follows:

Barrow No. 19

Type: Test well.
License to Prospect: 113H.
Latitude and Longitude: 20° 47′ 13″ S., 115° 22′ 30″ E.
Elevation: Ground level 130 feet, rotary table 141 feet.
Commenced: 2nd January, 1966.
Rig released: 10th January, 1966.
Total depth: 2,459 feet.
Bottomed in: Lower Cretaceous.
Status: Oil well, completed over the intervals 2,252 to 2,260 feet, and 2,266 to 2,284 feet in the Windalia Radiolarite.

Barrow No. 20

Type: Test well.
License to Prospect: 113H.
Latitude and Longitude: 20° 47′ 37″ S., 115° 24′ 51″ E.
Elevation: Ground level 109 feet, rotary table 120 feet.
Commenced: 12th January, 1966.
Rig released: 20th January, 1966.
Total depth: 2,465 feet.
Bottomed in: Lower Cretaceous.
Status: Oil well, completed over the intervals 2,334 to 2,326 feet, 2,320 to 2,310 feet, 2,304 to 2,298 feet, 2,280 to 2,266 feet, 2,260 to 2,244 feet and 2,238 to 2,230 feet in the Windalia Radiolarite.


WESTERN AUSTRALIA
SHOWING
OIL HOLDINGS AT 31ST DEC., 1966
LICENCE TO PROSPECT SHOWN THUS : ●102H
PERMIT TO EXPLORE SHOWN THUS : 30H
SCALE OF MILES
150 100 50 0 150
INDIAN
OCEAN
WYNDHAM
DERBY
BROOME
HALLS CREEK
PORT HEDLAND
ROEBOURNE
BARROW IS.
ONSLOW
CARNARVON
GERALDTON
KALGOORLIE
PERTH
COLLIE
ESPERANCE
ALBANY
238H
221H
232H
213H
253H
106H
251H
227H
30H
217H
233H
151H
152H
205H
153H
28H
235H
256H
257H
226H
134H
236H
135H
193H
136H
228H
172H
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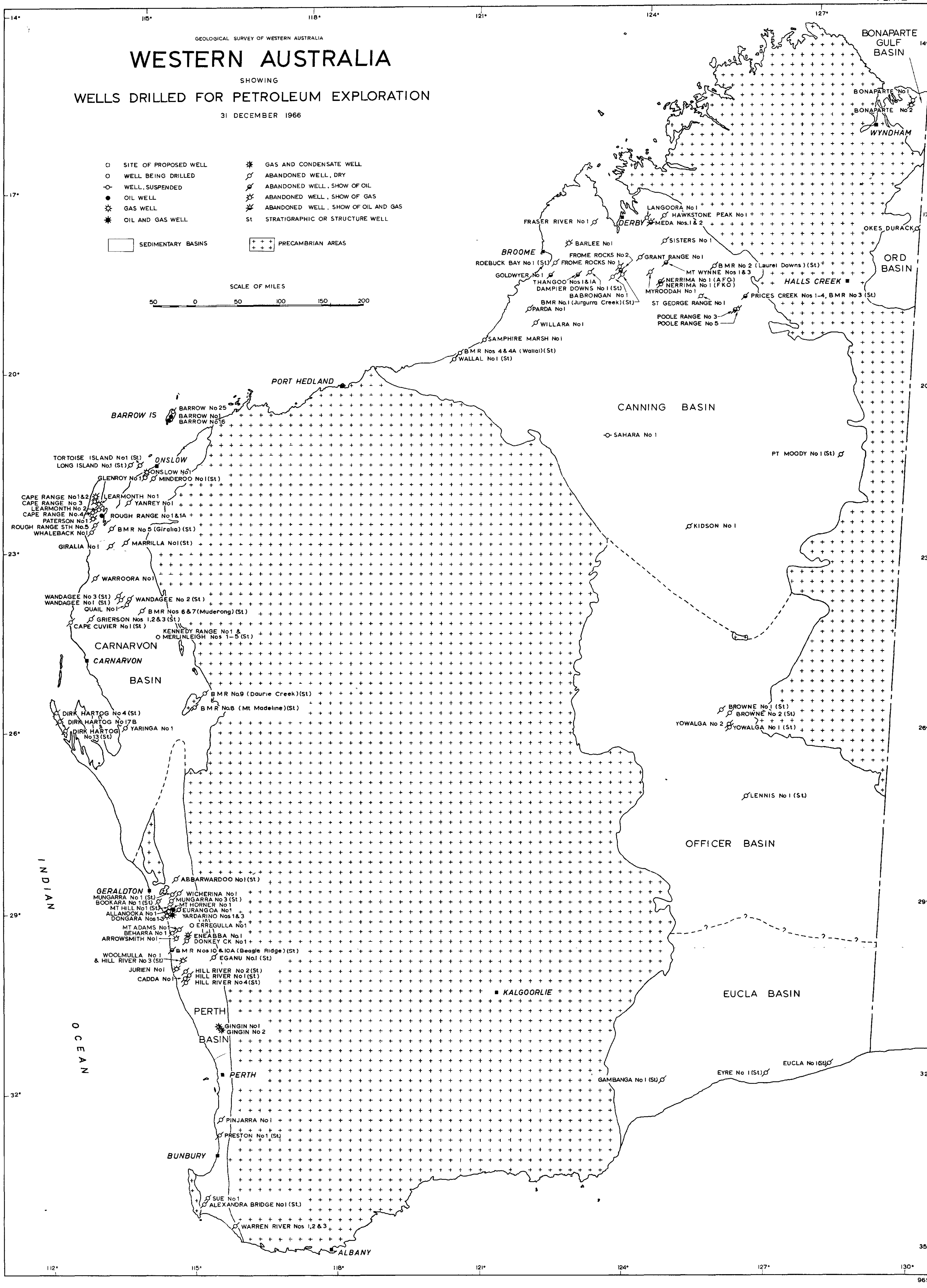
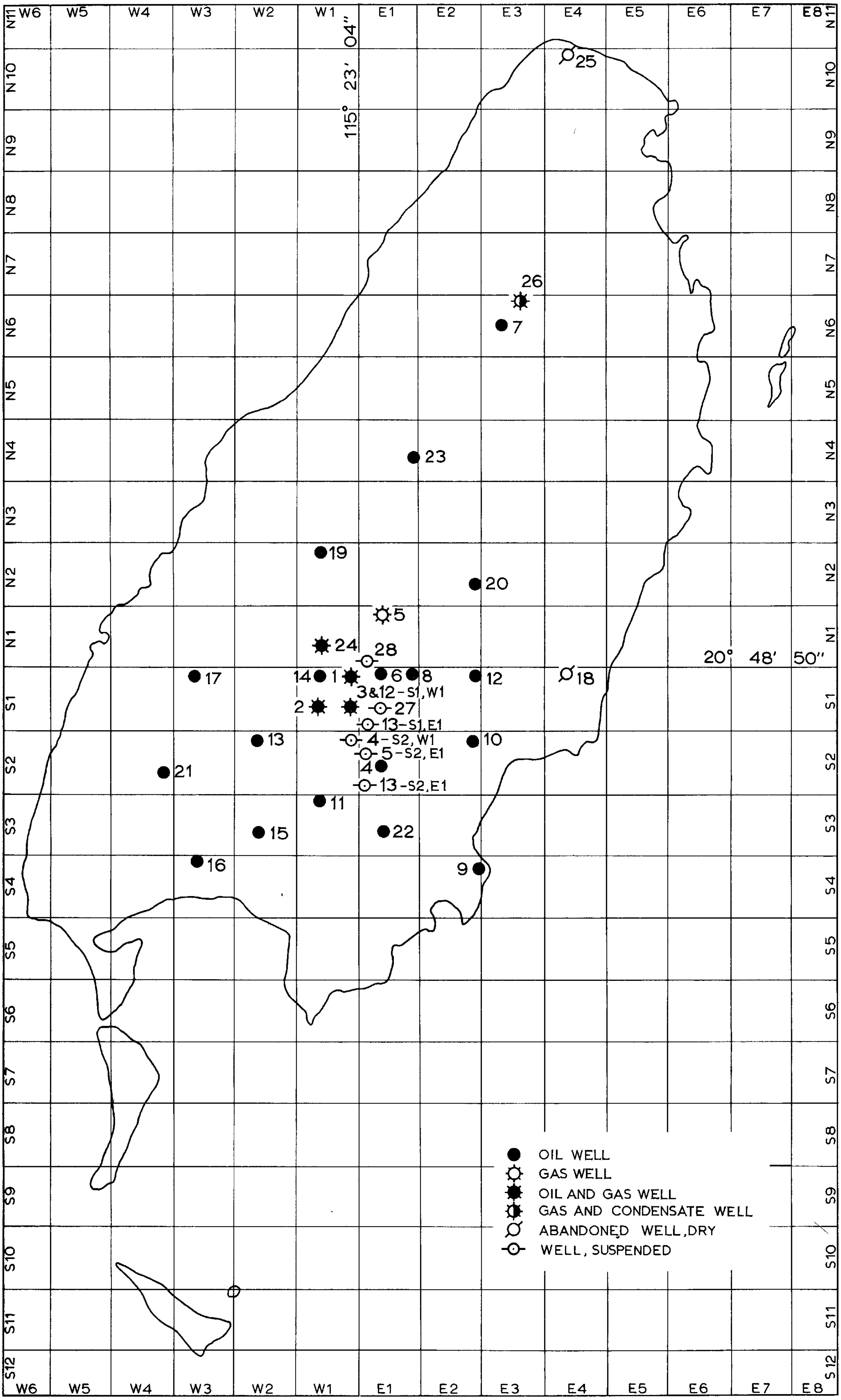
254H
175H
177H
240H
241H
242H
243H
127H


GEOLOGICAL SURVEY OF WESTERN AUSTRALIA
WESTERN AUSTRALIA
SHOWING
WELLS DRILLED FOR PETROLEUM EXPLORATION
31 DECEMBER 1966
SITE OF PROPOSED WELL
WELL BEING DRILLED
WELL, SUSPENDED
OIL WELL
GAS WELL
OIL AND GAS WELL
GAS AND CONDENSATE WELL
ABANDONED WELL, DRY
ABANDONED WELL, SHOW OF OIL
ABANDONED WELL, SHOW OF GAS
ABANDONED WELL, SHOW OF OIL AND GAS
St STRATIGRAPHIC OR STRUCTURE WELL
SEDIMENTARY BASINS
PRECAMBRIAN AREAS
SCALE OF MILES
50 0 50 100 150 200
BONAPARTE GULF BASIN
BONAPARTE No 1
BONAPARTE No 2
WYNDHAM
ORD BASIN
OKES DURACK
HALLS CREEK
CANNING BASIN
OFFICER BASIN
EUCLA BASIN
CARNARVON BASIN
PERTH BASIN
INDIAN OCEAN
DERBY
BROOME
PORT HEDLAND
BARROW IS
ONSLOW
CARNARVON
GERALDTON
KALGOORLIE
PERTH
BUNBURY
ALBANY
LANGOORA No 1
HAWKSTONE PEAK No 1
MEDA Nos. 1 & 2
FRASER RIVER No 1
SISTERS No 1
BARLEE No 1
FROME ROCKS No 2
FROME ROCKS No
GRANT RANGE No 1
ROEBUCK BAY No 1 (St)
GOLDWYER No 1
THANGOO Nos 1 & 1A
DAMPIER DOWNS No 1 (St)
BABRONGAN No 1
BMR No 1 (Jurgurra Creek) (St)
BMR No 2 (Laurel Downs) (St)
MT WYNNE Nos 1 & 3
NERRIMA No 1 (AFO)
NERRIMA No 1 (FKO)
MYROODAH No 1
ST GEORGE RANGE No 1
PRICES CREEK Nos 1-4, BMR No 3 (St)
POOLE RANGE No 3
POOLE RANGE No 5
PARDA No 1
WILLARA No 1
SAMPHIRE MARSH No 1
BMR Nos 4 & 4A (Wallal) (St)
WALLAL No 1 (St)
SAHARA No 1
PT MOODY No 1 (St)
KIDSON No 1
BROWNE No 1 (St)
BROWNE No 2 (St)
YOWALGA No 2
YOWALGA No 1 (St)
LENNIS No 1 (St)
EUCLA No 1 (St)
EYRE No 1 (St)
GAMBANGA No 1 (St)
BARROW No 25
BARROW No 1
BARROW No 16
TORTOISE ISLAND No 1 (St)
LONG ISLAND No 1 (St)
ONSLOW No 1
GLENROY No 1
MINDEROO No 1 (St)
CAPE RANGE No 1 & 2
CAPE RANGE No 3
LEARMONTH No 1
LEARMONTH No 2
CAPE RANGE No 4
PATERSON No 1
YANREY No 1
ROUGH RANGE No 1 & 1A
ROUGH RANGE STH No 5
WHALEBACK No 1
BMR No 5 (Giralia) (St)
GIRALIA No 1
MARRILLA No 1 (St)
WARROORA No 1
WANDAGEE No 3 (St)
WANDAGEE No 1 (St)
WANDAGEE No 2 (St)
QUAIL No 1
BMR Nos 6 & 7 (Muderong) (St)
GRIERSON Nos 1, 2 & 3 (St)
CAPE CUVIER No 1 (St)
KENNEDY RANGE No 1 &
MERLINLEIGH Nos 1-5 (St)
BMR No 9 (Daurie Creek) (St)
BMR No 8 (Mt Madeline) (St)
DIRK HARTOG No 4 (St)
DIRK HARTOG No 17B
DIRK HARTOG No 13 (St)
YARINGA No 1
ABBARWARDOO No 1 (St)
WICHERINA No 1
MUNGARRA No 1 (St)
MUNGARRA No 3 (St)
BOOKARA No 1 (St)
MT HORNER No 1
MT HILL No 1 (St)
EURANGOA No 1
ALLANOOKA No 1
YARDARINO Nos 1 & 3
DONGARA Nos 1-3
MT ADAMS No 1
ERREGULLA No 1
BEHARRA No 1
ENEABBA No 1
ARROWSMITH No 1
DONKEY CK No 1
BMR Nos 10 & 10A (Beagle Ridge) (St)
WOOLMULLA No 1
& HILL RIVER No 3 (St)
EGANU No 1 (St)
JURIEN No 1
HILL RIVER No 2 (St)
CADDA No 1
HILL RIVER No 1 (St)
HILL RIVER No 4 (St)
GINGIN No 1
GINGIN No 2
PINJARRA No 1
PRESTON No 1 (St)
SUE No 1
ALEXANDRA BRIDGE No 1 (St)
WARREN RIVER Nos 1, 2 & 3
9653

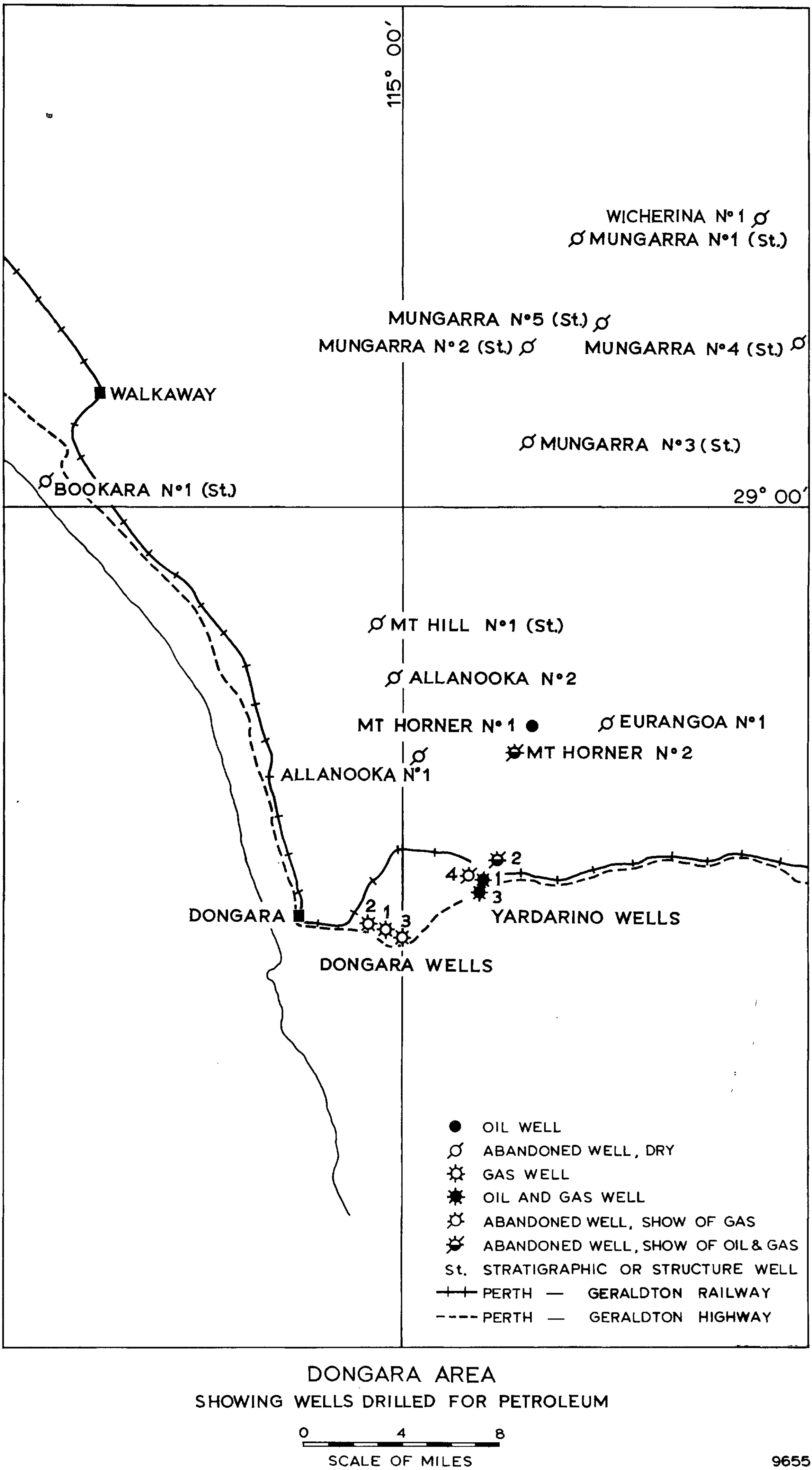


BARROW ISLAND

SHOWING WELLS DRILLED FOR PETROLEUM

9654

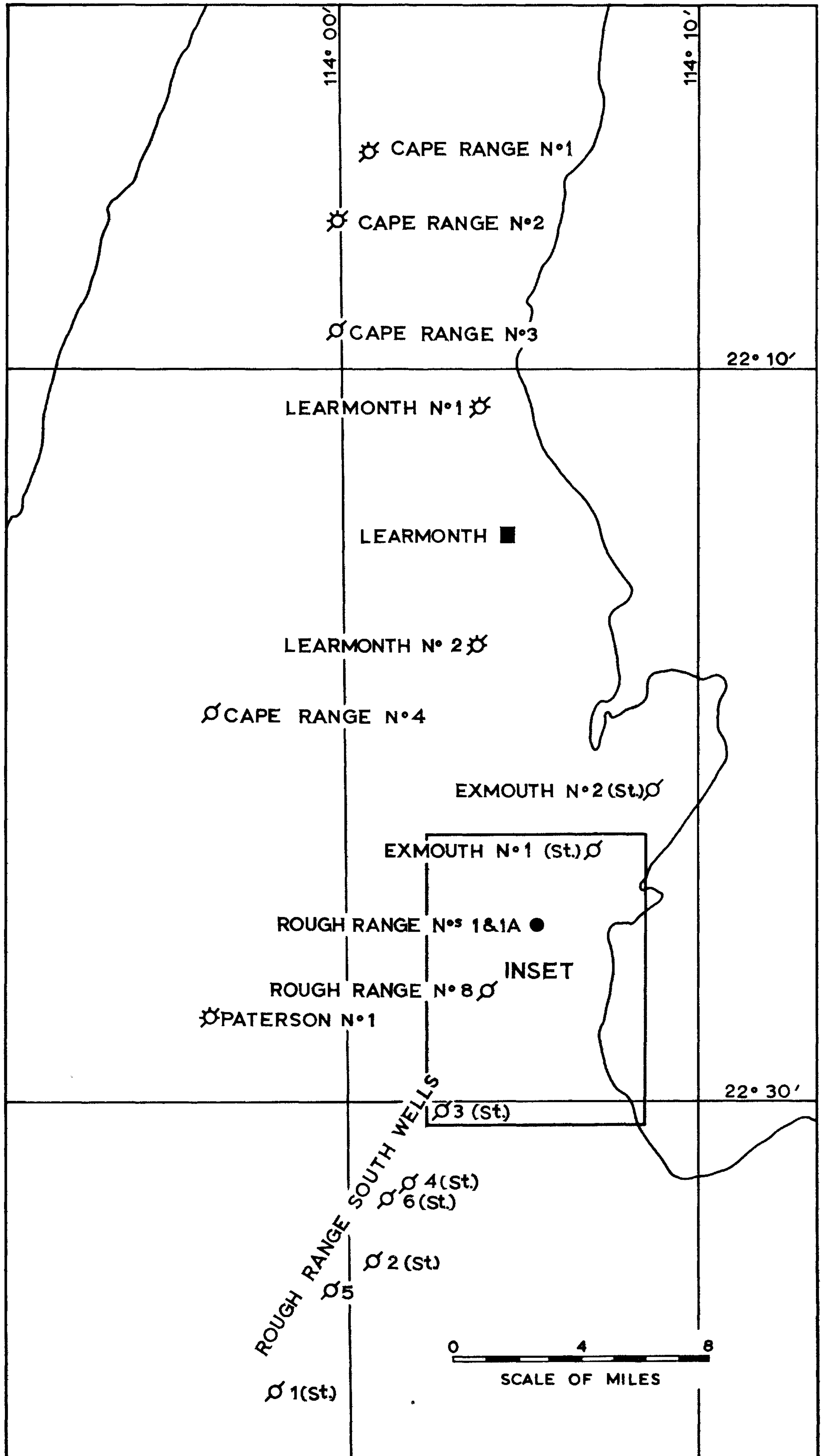
PLATE 24

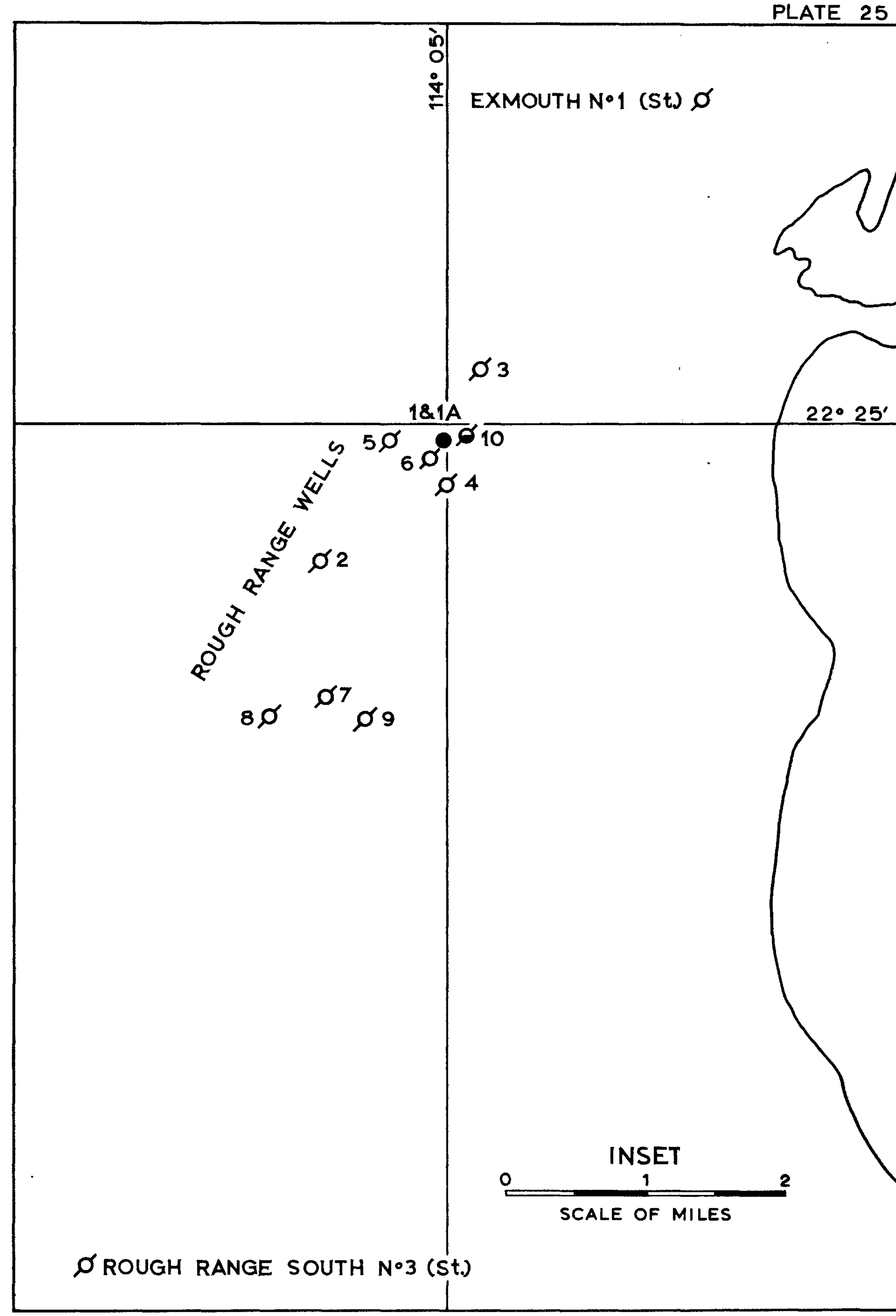


DONGARA AREA

SHOWING WELLS DRILLED FOR PETROLEUM

9655



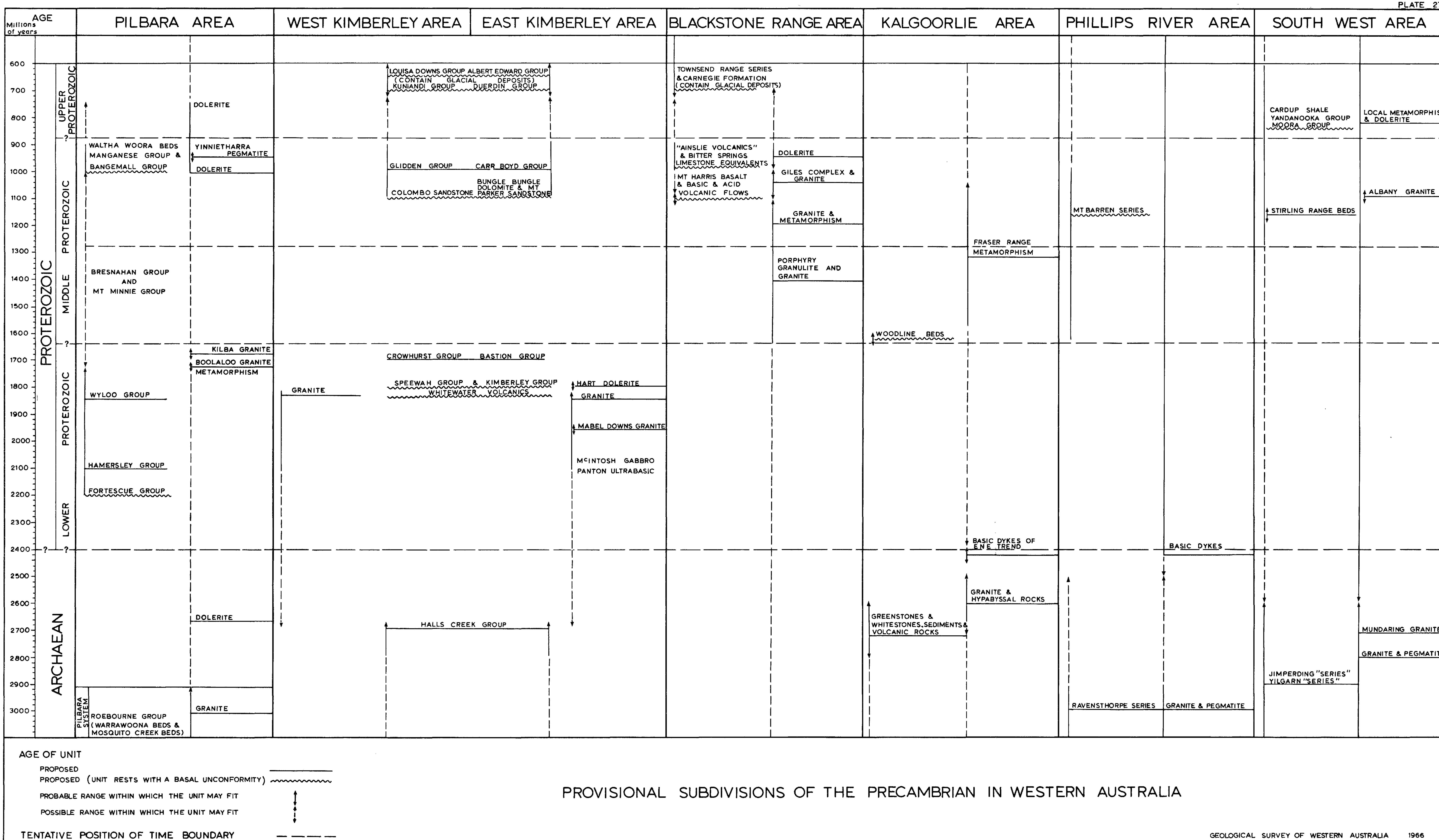


● OIL WELL
Ø ABANDONED WELL, DRY
Ø ABANDONED WELL, SHOW OF OIL
☼ ABANDONED WELL, SHOW OF GAS
St. STRATIGRAPHIC OR STRUCTURE WELL

CAPE RANGE – ROUGH RANGE AREA
SHOWING WELLS DRILLED FOR PETROLEUM

9656

PLATE 27



PROVISIONAL SUBDIVISIONS OF THE PRECAMBRIAN IN WESTERN AUSTRALIA

GEOLOGICAL SURVEY OF WESTERN AUSTRALIA 1966

9683

Barrow No. 21

Type: Test well.
License to Prospect: 113H.
Latitude and Longitude: 20° 50′ 17″ S., 115° 25′ 11″ E.
Elevation: Ground level 95 feet, rotary table 106 feet.
Commenced: 22nd January, 1966.
Rig released: 30th January, 1966.
Total depth: 2,435 feet.
Bottomed in: Lower Cretaceous.
Status: Oil well, completed over the intervals 2,258 to 2,284 feet, and 2,318 to 2,325 feet in the Windalia Radiolarite.

Barrow No. 22

Type: Test well.
License to Prospect: 113H.
Latitude and Longitude: 20° 51′ 09″ S., 115° 23′ 27″ E.
Elevation: Ground level 50 feet, rotary table 61 feet.
Commenced: 2nd February, 1966.
Rig released: 12th February, 1966.
Total depth: 2,709 feet.
Bottomed in: Lower Cretaceous.
Status: Oil well, completed over the intervals 2,489 to 2,501 feet, and 2,532 to 2,538 feet in the Windalia Radiolarite.

Barrow No. 23

Type: Test well.
License to Prospect: 113H.
Latitude and Longitude: 20° 45′ 55″ S., 115° 23′ 53″ E.
Elevation: Ground level 189 feet, rotary table 200 feet.
Commenced: 15th February, 1966.
Rig released: 21st February, 1966.
Total depth: 2,580 feet.
Bottomed in: Lower Cretaceous.
Status: Oil well, completed over the interval 2,362 to 2,381 feet in the Windalia Radiolarite.

Barrow No. 24

Type: Test well.
License to Prospect: 113H.
Latitude and Longitude: 20° 48′ 30″ S., 115° 22′ 30″ E.
Elevation: Ground level 169 feet, rotary table 180 feet.
Commenced: 24th February, 1966.
Rig released: 1st April, 1966.
Total depth: 7,349 feet.
Bottomed in: Upper Jurassic.
Status: Oil and gas well, completed over the interval 6,218 to 6,222 feet in Jurassic sediments.

Barrow No. 25

Type: Test well.
License to Prospect: 113H.
Latitude and Longitude: 20° 40′ 17″ S., 115° 26′ 19″ E.
Elevation: Ground level 53 feet, rotary table 64 feet.
Commenced: 12th April, 1966.
Rig released: 17th May, 1966.
Total depth: 8,314 feet.
Bottomed in: Upper Jurassic.
Status: Dry, plugged and abandoned.

Barrow No. 26

Type: Test well.
License to Prospect: 113H.
Latitude and Longitude: 20° 43′ 41 ″ S., 115° 25′ 32″ E.
Elevation: Ground level 171 feet, rotary table 183 feet.
Commenced: 21st May, 1966.
Rig released: 3rd July, 1966.
Total depth: 7,875 feet.
Bottomed in: Upper Jurassic.
Status: Gas and condensate well, completed over the interval 5,550 to 5,555 feet in Lower Cretaceous sandstone.

Barrow No. 27

Type: Test well.
License to Prospect: 113H.
Latitude and Longitude: 20° 49′ 24″ S., 115° 23′ 28″ E.
Elevation: Ground level 217 feet, rotary table 228 feet.
Commenced: 5th July, 1966.
Rig released: 22nd July, 1966.
Total depth: 7,304 feet.
Bottomed in: Upper Jurassic.
Status: Suspended awaiting completion as a producing well.

Barrow No. 28

Type: Test well.
License to Prospect: 113H.
Latitude and Longitude: 20° 48′ 45″ S., 115° 23′ 12″ E.
Elevation: Ground level 188 feet, rotary table 199 feet.
Total depth: 7,000 feet.
Commenced: 5th August, 1966.
Rig released: 25th August, 1966.
Bottomed in: Upper Jurassic.
Status: Suspended, awaiting completion as a producing well.

Barrow 12-S1, W1

Type: Development well.
License to Prospect: 113H.
Location: Twin well with Barrow No. 3.
Elevation: Ground level 150 feet, rotary table 161 feet.
Commenced: 4th December, 1966.
Rig released: 8th December, 1966.
Total depth: 2,361 feet.
Bottomed in: Lower Cretaceous.
Status: Suspended, awaiting testing.

Barrow 13-S1, E1

Type: Development well.
License to Prospect: 113H.
Location: 20 chains south and 20 chains east of Barrow No. 3.
Elevation: Ground level 167 feet, rotary table 178 feet.
Commenced: 9th December, 1966.
Rig released: 13th December, 1966.
Total depth: 2,354 feet.
Bottomed in: Lower Cretaceous.
Status: Suspended, awaiting testing.

Barrow 4-S2, W1

Type: Development well.
License to Prospect: 113H.
Location: 40 chains south of Barrow No. 3.
Elevation: Ground level 185 feet, rotary table 195 feet.
Commenced: 14th December, 1966.
Rig released: 17th December, 1966.
Total depth, 2,300 feet.
Bottomed in: Lower Cretaceous.
Status: Suspended, awaiting testing.

Barrow 5-S2, E1

Type: Development well.
License to Prospect: 113H.
Location: 60 chains south and 20 chains east of Barrow No. 3.
Elevation: Ground level 141 feet, rotary table 151 feet.
Commenced: 18th December, 1966.
Rig released: 22nd December, 1966.
Total depth: 2,290 feet.
Bottomed in: Lower Cretaceous.
Status: Suspended, awaiting testing.

Barrow 13-S2, E1

Type: Development well.
License to Prospect: 113H.
Location: 100 chains south and 20 chains east of Barrow No. 3.
Elevation: Ground level 85 feet, rotary table 96 feet.
Commenced: 22nd December, 1966.
Rig released: 1st January, 1967.
Total depth: 2,198 feet.
Bottomed in: Lower Cretaceous.
Status: Suspended, awaiting testing.

PERMIT TO EXPLORE 226H

Permit to Explore 226H is held by West Australian Petroleum Pty. Ltd. and is farmed out to Continental Oil Company of Australia Ltd. and Australian Sun Oil Company Ltd. It covers the southern part of the Carnarvon Basin. One test well, Yaringa No. 1, was drilled in the permit area in 1966. Details are as follows:

Yaringa No. 1
Type: Test well.
License to Prospect: 172H.
Latitude and Longitude: 26° 03′ 58″ S., 114° 21′ 35″ E.
Elevation: Ground level 70 feet, kelly bushing 88 feet.
Commenced: 2nd July, 1966.
Rig released: 18th August, 1966.
Total depth: 7,508 feet.
Bottomed in: ?Ordovician.
Status: Dry, plugged, and abandoned.

PERMIT TO EXPLORE 227H

Permit to Explore 227H is held by West Australian Petroleum Pty. Ltd. and is farmed out to Continental Oil Company of Australia Ltd. and Australian Sun Oil Company Ltd. One test well, St. George Range No. 1, was drilled in this permit area during 1966. Details are as follows:

St. George Range No. 1
Type: Test Well.
License to Prospect: 132H.
Latitude and Longitude: 18° 41′ 30″ S., 125° 08′ 11″ E.
Elevation: Ground level 566 feet, kelly bushing 584 feet.
Commenced: 16th September, 1965.
Rig released: 15th May, 1966.
Total depth: 14,558 feet.
Bottomed in: Lower Carboniferous.
Status: Dry, plugged, and abandoned.

PERMIT TO EXPLORE 228H

Permit to Explore 228H is held by West Australian Petroleum Pty. Ltd. and is farmed out to French Petroleum Co. (Aust.) Pty. Ltd. and Australian Aquitaine Petroleum Pty. Ltd. It is situated in the central Perth Basin. Two wells, Beharra No. 1 and Donkey Creek No. 1, were drilled in the permit area during 1966. Details are as follows:

Beharra No. 1
Type: Test well.
License to Prospect: 177H.
Latitude and Longitude: 29° 29′ 10″ S., 115° 00′ 45″ E.
Elevation: Ground level 74 feet, kelly bushing 95 feet.
Commenced: 28th November, 1966.
Rig released: 16th December, 1966.
Total depth: 6,744 feet.
Bottomed in: Precambrian.
Status: Dry, plugged, and abandoned.

Donkey Creek No. 1
Type: Test well.
License to Prospect: 176H.
Latitude and Longitude: 29° 37′ 35″ S., 115° 17′ 25″ E.
Elevation: Ground level 350 feet, kelly bushing 365 feet.
Commenced: 30th August, 1966.
Rig released: 21st October, 1966.
Total depth: 12,640 feet.
Bottomed in: Lower Triassic.
Status: Dry, plugged, and abandoned.

GEOPHYSICAL OPERATIONS

Seismic

During 1966 seismic surveys were conducted in the Perth, Carnarvon, Canning, and Bonaparte Gulf Basins. This work was distributed as follows:

Company	Permit	Basin	Party Months
West Australian Petroleum Pty. Ltd.	27H	Perth	24.42 (land) 1.9 (marine)
do. do. do.	28H	Carnarvon	5.81 (land) 0.31 (marine)
do. do. do.	30H	Canning	8.65 (land)
do. do. do.	217H	Carnarvon	5.30 (marine)
do. do. do.	225H	Perth	0.10 (marine)
Gewerkschaft Elwerath	251H	Canning	5.0 (land)
Continental Oil Co. of Australia Ltd.	226H	Carnarvon	1.32 (land)
do. do. do.	227H	Canning	0.65 (land)
Arco Ltd. and Anacapa Corp.	127H	Bonaparte Gulf	2.0 (marine)
do. do. do.	221H	do.	7.0 (marine)
B.O.C. of Australia Ltd.	213H	Canning	0.57 (marine)
French Petroleum Co. (Aust.) Pty. Ltd.	228H	Perth	5.5 (land)
BP Petroleum Development Aust. Pty. Ltd.	193H, 236H	Perth	0.5 (marine)
Canadian Superior Oil (Aust.) Pty. Ltd.	235H	Carnarvon	2.5 (marine)

Gravity

A gravity survey was carried out during the year in the Perth Basin, on Permit to Explore 228H, for French Petroleum Company (Aust.) Pty. Ltd. This amounted to 5·5 party months.

Magnetic

West Australian Petroleum Pty. Ltd. conducted an aeromagnetic survey over 2,665 line miles on Permit to Explore 30H in the Canning Basin. A ground magnetic survey totalling 390 line miles was carried out by Gewerkschaft Elwerath on Permit to Explore 251H in the Canning Basin.

GEOLOGICAL OPERATIONS

Field geological studies were carried out by oil exploration companies in the Carnarvon, Canning, and Officer Basins. They were distributed as follows:

Company	Permit	Basin	Geologist Months
West Australian Petroleum Pty. Ltd.	30H	Canning	3
Gewerkschaft Elwerath	251H	Canning	4
French Petroleum (Aust.) Pty. Ltd.	....	Canning & Officer	2

Photogeological work was conducted by Coastal Petroleum N. L. over Permits to Explore 172H–177H (1·7 geologist months), and an airborne Profile Recording Survey was carried out over Permits to Explore 151H and 152H by Australian Aquitaine Petroleum Pty. Ltd. (party of 6 for 4 months). The Geological Survey of Western Australia continued its mapping programme in the Eucla Basin (6 geologist months) and Perth Basin (3·5 geologist months).

A LATE PRECAMBRIAN BELT OF VULCANICITY IN CENTRAL AUSTRALIA

by R. C. Horwitz and J. L. Daniels

ABSTRACT

In central Australia crystalline rocks occur between the Amadeus, Eucla, and Officer basins. These rocks are part of a Precambrian complex referred to in South Australia as the Musgrave—Mann Complex. The complex is part of a tectonic unit which has been referred to as the Pitjentara Shield and the Musgrave Block.

These crystalline rocks have been mapped in Western Australia on parts of the Cooper, Scott, and Talbot 1:250,000 Sheet areas by the Geological Survey of Western Australia, and mapped on the Rawlinson Sheet area by the Bureau of Mineral Resources.

The present stage of mapping allows a better understanding of the distribution and chronology of volcanic rocks of the region and corre-

lations can be suggested with their possible equivalent in other areas. The occurrences define a belt with vulcanicity closely related to a belt with contemporaneous evaporite beds, leading to diapirism. These all define a palaeogeographic trend in Australia for the upper Middle Proterozoic.

CENTRAL AUSTRALIA

A sequence of interbanded basic, acid, and intermediate volcanic flows has been recognised in the Talbot, Cooper, Scott, and Rawlinson Sheet areas of Western Australia and in the Bloods Range Sheet area of the Northern Territory. Their continuity, by structural repetition, has been established in the Scott and Cooper Sheet areas (Horwitz and others, 1967). In the Scott, Rawlinson (W.A.), and Bloods Range (N.T.) Sheet areas, their continuity has also been established by structural repetition. Forman and Hancock (1964) refer to the lavas as the Mount Harris Basalt, but the unit is known to include acid flows. The consanguinity of these volcanic rocks with those of the Talbot Sheet is recognised by comparison of sequences and by results of age determinations.

On the Cooper Sheet, the base of this mixed volcanic sequence is not exposed because it is masked by the intrusion of granite and gabbro-granophyre sheets and these rocks are folded in sympathy (Horwitz and others, 1967). A sequence of basalts, not intruded by granite, and a basal conglomerate rest unconformably on the eroded core of an anticline which involves the mixed volcanic suite and both sheets of plutonic rocks. The sequence of mixed volcanic rocks (at Tollu & Skirmish Hill), intruded by granite and overlain unconformably (at McDougall Bluff) by basalts, is thus similar to the sequence described on the Talbot Sheet in the Warburton Range (Horwitz and Sofoulis, 1963). The large porphyry bodies formerly considered to be intrusive are now known to be volcanic flows, at least in part.

Acidic volcanic rocks, in the mixed volcanic suite, have been dated by W. Compston at the Australian National University. Samples from the Tollu area, on the Cooper Sheet, and from the Warburton area, on the Talbot Sheet, indicate an age of the order of 1,100 m.y. (Compston pers. comm. 1965).

Thomson (1966), in a review on the age of the metamorphic rocks of the region, rightly suggested that the Mount Harris Basalt and the volcanic rocks of Skirmish Hill could be cogenetic but his reference to the "Skirmish Hill Area (W.A.)" is ambiguous. The basal conglomerate, referred to in his table (p. 223) for the Skirmish Hill area (Cooper Sheet) probably applies to the younger set of basalts of McDougall Bluff, and, because of an unfortunate selection of descriptions for different parts of the sequence from different authors, in the Warburton Range area (Talbot Sheet) this author's table wrongly implies that basic dykes are older than the basic volcanic rocks above the unconformity.

The basal contact of the mixed flows is, however, exposed in the northern part of the crystalline complex, where the plutonic sheets that intrude the volcanic assemblage do not persist as large bodies. On the Scott Sheet, in the Giles Creek region, the Mount Harris Basalt rests unconformably on a basement of rapakivi-like granite (a granite packed with large feldspar ovoids, but not known to carry oligoclase-rimmed potash feldspars. This is the rock referred to as pyterlite by Eskola, 1963). The relationship is locally obscured by the younger granite which contains large phenocrysts of feldspar, some rounded and others euhedral. The presence of an unconformity at this stratigraphic position in this general area, although already recognised by Forman, was later rejected (Forman and Hancock, 1964), probably because of the similarity in a porphyritic facies between the pyterlite, the younger granite, and some of the coarsely porphyritic flows in the mixed volcanic suite.

On the northern side of this Musgrave Block, Forman and Hancock show that the crystalline complex containing the Mount Harris Basalt is overlain unconformably by the Dean Quartzite followed by the Pinyinna Beds which these authors equate with the Heavitree Quartzite and Bitter Springs Limestone (Joklik, 1955) respectively. These are overlain by the Areyonga Formation (Prichard and Quinlan, 1962), or its equivalents, which contain glacial beds, recognised as part of the Sturtian Series by Mawson (1957). There is no record of defined volcanic flows in the Bitter Springs Limestone though volcanic tuffs have been recognised (Webb, 1959).

On the Talbot Sheet, boulder beds that overlie unconformably the younger basalt have been equated with the glacials of the Sturtian Series of the Adelaide System (Horwitz, 1966). These are younger than the basic dykes in the region, a relationship already established to the east on the Alberga Sheet (S.A.) by Coats (1963).

Little or no sediment is interstratified with the mixed volcanic rocks on the Cooper Sheet. On the Scott Sheet (in the Giles Creek area, Kathleen Range, and Dean Range) phyllitic siltstone and sandstone occur, interstratified with lava flows. These mixed flows are interlayered with dolomite and chert in the Warburton Range on the Talbot Sheet (Sofoulis, 1962). On the northern part of the Cooper Sheet, the two plutonic sheets, intrusive into this volcanic sequence, have their maximum development and it is possible that these are aspects of related igneous activity (Horwitz and others, 1967; Daniels, 1967).

It is concluded that mixed acid and basic lavas were extruded within a fairly well defined area in the Musgrave Block. It is part of an igneous complex forming the youngest crystalline basement to the Upper Proterozoic glacial deposits which are so well developed in parts of the Adelaide System.

CORRELATIONS WITH OTHER REGIONS

Walpole and others (1965) tentatively correlated the Mount Harris Basalt with volcanic rocks known to be older than 1,400 m.y., from the northern part of the Northern Territory. They also correlated them with unnamed volcanic rocks on the northwestern edge of the Amadeus Basin. The first correlation conflicts with recent age determinations and is discarded. The second correlation is believed to apply to rocks described by Wells and others (1961) on the northeastern part of the MacDonald Sheet, which lies north of the Scott Sheet. These authors describe, amongst other rock types, porphyritic dacite and rhyolite associated with shale, siltstone, sandstone, and chert in the region below the Heavitree Quartzite equivalents. There is, to our knowledge, no other record of vulcanicity older than the Heavitree Quartzite and ranging to the order of 1,100 m.y. on the northern edge of the Amadeus Basin, towards the east.

Correlations have been suggested for the volcanic rocks of the Musgrave Block with those of the Pilbara-Murchison general area of Proterozoic rocks. Thomson (1966) has proposed correlations with units of the Mt. Bruce Super-group, but these are contradicted by comparison with age determinations in Leggo and others (1965). The correlation with rocks of this area had been proposed previously, in a general way, by Sofoulis (1962) and appears to apply to a grouping of rocks that overlie the Archaean, south and west of Lake Carnegie in the Kingston Sheet area where four bands of rhyolite have been recognised, interlayered with sediment and possible tuffs. According to W. R. Jones (pers. comm. 1966) possible acidic lavas occur in the Edmund Sheet area in the Kiangi Creek Formation, a part of the Bangemall Group (Daniels, 1966).

Volcanic rocks have been recognised in the general area north of Wiluna, on the Glengarry, Peak Hill, and Nabberu Sheets and in the Billeranga Hills on the Perenjori Sheet, north of Perth, where thin lava flows have been identified. There are references to possible tuffs but no reference to defined flows in parts of the Precambrian between longitude 124° and the west coast, in rock

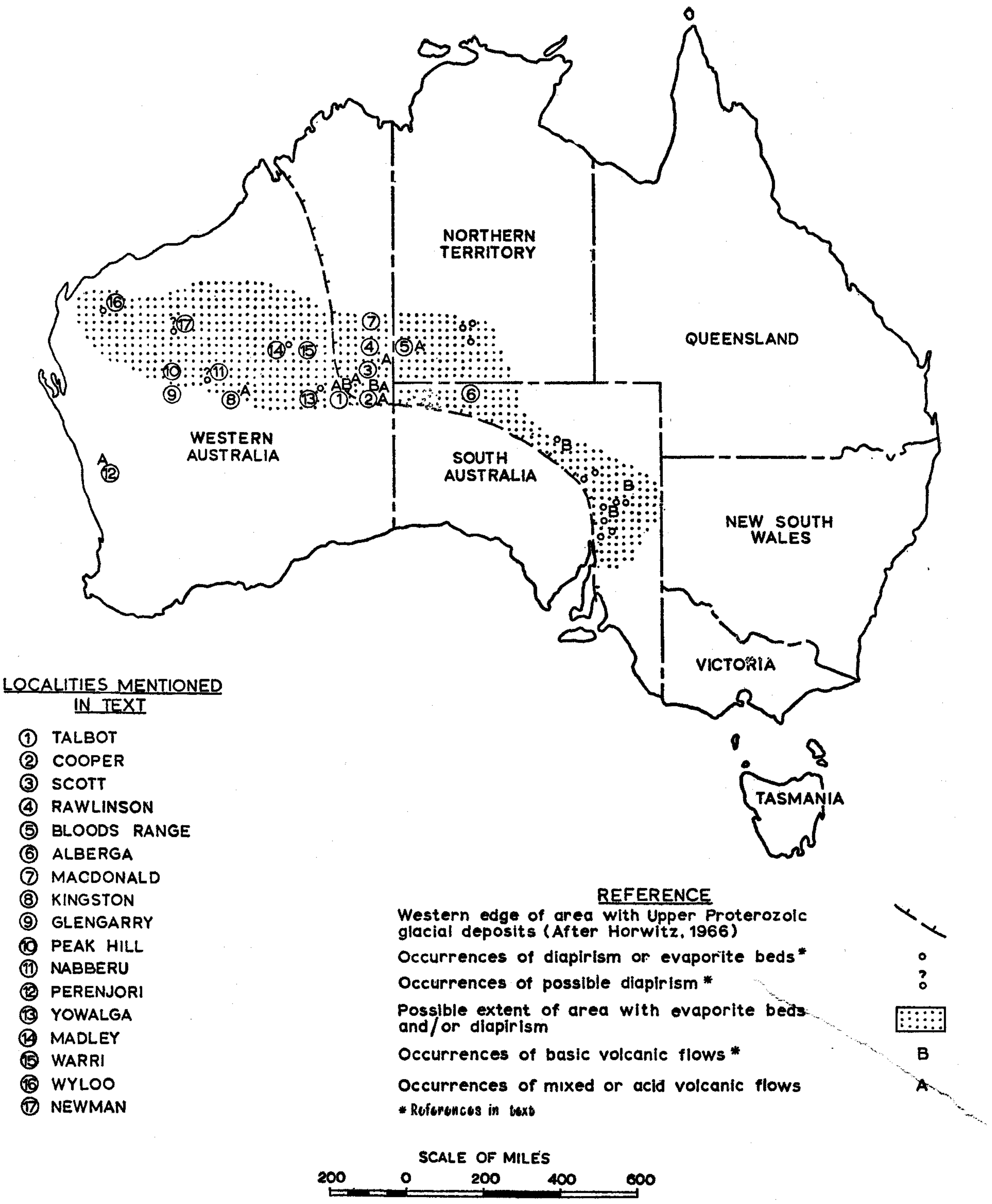


FIGURE 11
DISTRIBUTION IN AUSTRALIA OF LATE MIDDLE PROTEROZOIC VULCANICITY AND EVAPORITE BEDS

sequences that have been recognised to equate possibly with those of the Musgrave Block. These areas are depicted in the 1966 edition of the Geological Map of Western Australia.

There is no record of vulcanicity of comparable age in the Kimberley region of Western Australia.

On the Yowalga Sheet, 50 miles west of the last outcrops on the Talbot Sheet, basalts were intersected in depth in association with red-beds and evaporite deposits and were assigned to the late Precambrian.

Let us consider both sequences of flows in the Musgrave Block as a whole and include vulcanism that would range from 1,200 m.y. to the base of the late Precambrian glacial deposits. The occurrences of volcanic flows, here included in this grouping (Figure 11), suggests that they are in an east-west trending belt. It is tempting to extend this belt eastwards to include some of the volcanic rocks of the northern and central Flinders Range of South Australia, all now included in the Willouran Series (Crawford, 1963). These volcanic rocks appear in piercement folds as well as in the layered sequence. Both the diapirism and the lava flows are a feature of the central and northern Flinders Range; no defined flows are recorded from the southern part of the Range.

The Willouran Series has been dated by Compston and others (1966) with a preferred age of about 1,400 m.y. but these authors leave open the possibility of the Willouran Series including rocks as young as 900 m.y.

If our correlation is adopted, there is sympathy in distribution and trend between volcanic flows and evaporite beds, believed to be indicative of a palaeogeographic zone marginal to a continent. These are plotted in Figure 11 from the data available in literature (Coats, 1965; Cook, 1966; Wells, 1963).

In the North-West Division of Western Australia, diapirism has been noted in the Bangemall Group near Mt. Florry on the Wyloo Sheet (Daniels, 1966). Previously un-recorded field observations suggests diapirism in the Newman and Nabberu Sheets.

The upper part of the Adelaide System has a general northwesterly trend in its distribution which is believed to be controlled by an old shore line (Horwitz, 1966).

The Adelaide System, as redefined (Thomson and others, 1964), is believed to be a complex grouping, at the intersection of separate units in the Precambrian. From evidence in Western Australia on age determinations carried out by W. Compston, a part of the Adelaide System can be assigned to the upper part of the Middle Proterozoic.

It is concluded that the upper Middle Proterozoic in Australia is controlled by an east-west palaeogeography, while the palaeogeography of the Upper Proterozoic runs north-south across Australia.

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A ZONE OF ARCHAEAN CONGLOMERATES IN THE EASTERN GOLDFIELDS, WESTERN AUSTRALIA

by R. C. Horwitz, M. J. B. Kriewaldt, I. R. Williams and J. J. G. Doepel

ABSTRACT

Archaean conglomerates in the Eastern Goldfields of Western Australia lie in a zone that is oblique to the main fold axes and extends from Southern Cross and Norseman to north of Laverton. It is considered to reflect an Archaean chain of volcanic islands. In this zone oligomictic conglomerates are associated with flows and sills of felsic rocks. By contrast polymictic conglomerates are not associated with eruptive rocks.

INTRODUCTION

Archaean conglomerates in the Eastern Goldfields of Western Australia occur in a zone trending northeasterly through Kalgoorlie, and are believed to reflect the Archaean geography (Figure 12). Both oligomictic and polymictic conglomerates are found and are described in Western Australian Geological Survey Bulletins (Nos. 21, 42, 47, 56, 66, 71, 73, 79, 84, 97, 103, and 114) and annual reports (for 1947, 1960, 1961, and 1963). Age determinations by A. Turek, of the

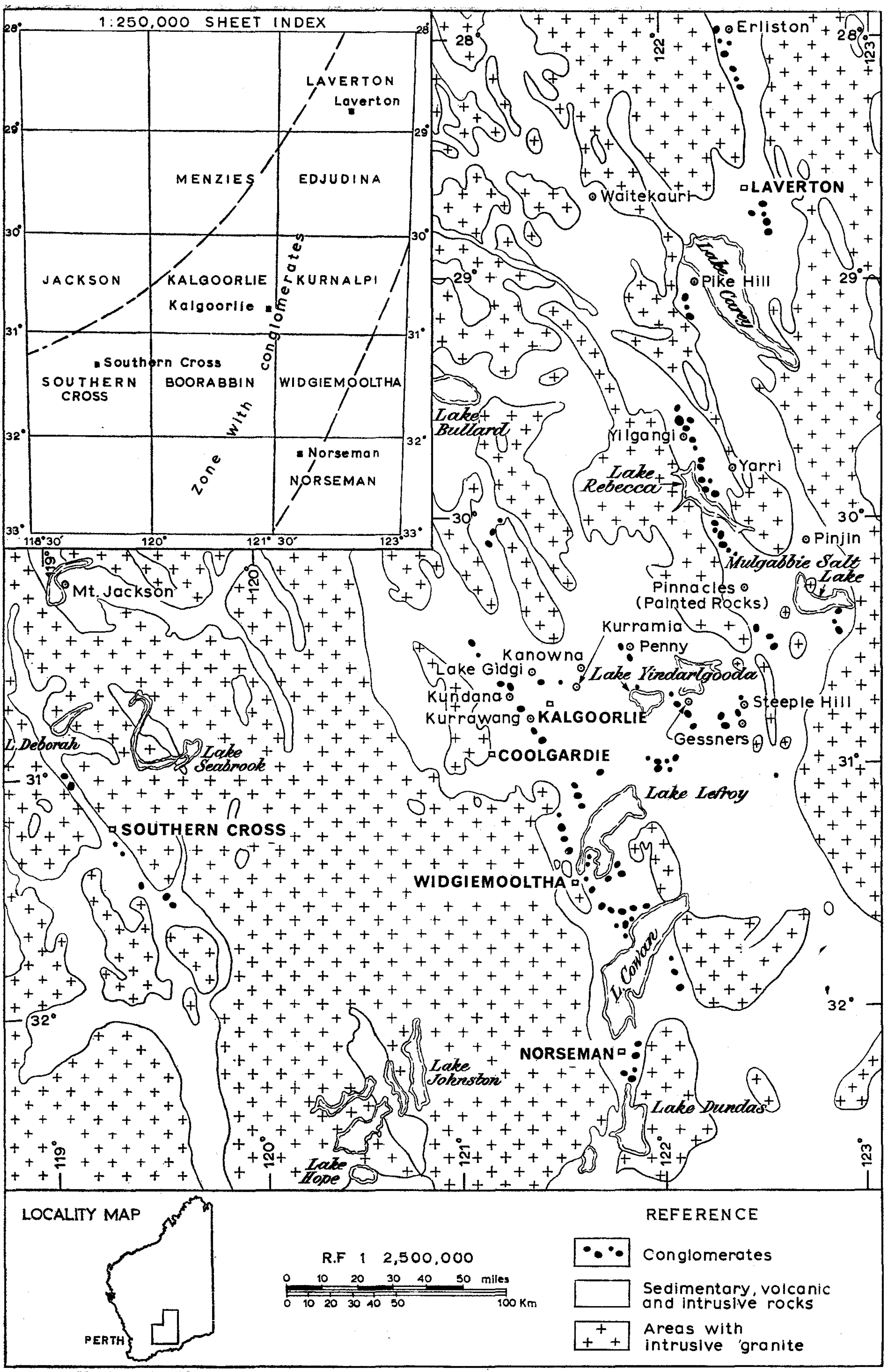

FIGURE 12 ARCHAEAN CONGLOMERATES IN THE EASTERN GOLDFIELDS OF WESTERN AUSTRALIA

Australian National University, confirm an Archaean age. Other conglomerates at Mount Jackson and in the Woodline Beds are Proterozoic.

POLYMICTIC CONGLOMERATES

The polymictic conglomerates are typified by the conglomerates at Kurrawang. They occur as lenses within beds of metamorphosed greywacke. The most abundant clasts are chert and jaspilite, fine-grained felsic rocks with porphyritic texture, quartz, and quartzite. Rock types that have been recorded from the clasts in the Kurrawang area are shown in Table I.

Table 1

ROCKS RECORDED FROM CONGLOMERATES AT KURRAWANG

Jasperoid and hematite-bearing quartz, black chert, quartz, quartzite, quartz- and feldspar-porphyries, felsite, granite, etc.	G.S.W.A. Bull. 42.
Hematite-jasper, liver-coloured quartzite, and quartz- and albite-porphyries.	Thomson, 1913
Quartz, quartzite (?), jasperoid rock (often banded), and albite-porphyry.	Maclaren and Thomson, 1913.
Aplite, pegmatite, quartz-porphyry and feldspar-porphyry, granitic pebbles.	Maclaren and Thomson, 1913.
Limestone, porphyry, quartzite, granite, and almost pure magnetite.	Chewings, 1896
Acid porphyry, felsitic intermediate porphyry, hornblende porphyry, fine-grained aggregate of mica and feldspar.	G.S.W.A. Bull. 56.
Quartzite, granite, gneissic rock, etc.	Larcombe, 1912.
Porphyry, slate, schist, quartz, etc.	Larcombe, 1912.

It is noteworthy that clasts of granite are very rare in the polymictic conglomerates, although they have been recognized by several workers. We agree with Maclaren and Thomson that the paucity of granite clasts probably means that there were no large areas of granite exposed in the distributive province during sedimentation. It is possible that the granite clasts were eroded from small bodies which were composed mainly of fine-grained rocks of felsic composition.

Most of the clasts are pebble sized although at many localities cobbles predominate and there are several occurrences containing boulders. They are set in a matrix of cleaved and metamorphosed greywacke, similar to that of the surrounding beds. In many areas, the clasts are deformed and stretched parallel to the cleavage planes, and where the clasts are closely packed together, they are moulded around each other. Before deformation, many of the clasts were apparently rounded. During metamorphism, biotite and chlorite have grown in the matrix and in some of the clasts.

OLIGOMICTIC CONGLOMERATES

In contrast to the polymictic conglomerates are the oligomictic conglomerates in which practically all the clasts are of a rock type that has been called ' porphyry '. These clasts all have a porphyritic texture and belong to a felsic suite with rock types ranging from rhyolite to dacite and, less commonly, to andesite. Many of these conglomerates directly overlie large bodies of porphyry. In some deposits, the fragments of porphyry are almost entirely angular and these are better termed breccias. Clasts in the oligomictic conglomerates range from pebble size to boulder size, some of the boulders being over 12 feet long. In some, the elements are packed together closely; in others they are scattered in a greywacke matrix. Close resemblances between the clastic albite and the albite phenocrysts of the porphyry clasts have been recognized by Trendall who also noted that many of the darker coloured fragments, which had been called basalt in hand specimen, are porphyry with a metamorphic biotite.

DISTRIBUTION

Conglomerates are widespread in the area of the Widgiemooltha Sheet and their significance has been discussed by Horwitz and Sofoulis (1965). Among their conclusions are:

1. There are two sequences separated by an unconformity.

2. The upper sequence rests on rhyolite flows or on large ' porphyry ' sills.

3. There are no large ' porphyry ' sills or rhyolites in the upper sequence.

4. The conglomerates are restricted to the upper sequence.

5. The clasts of the conglomerates were eroded from rocks of both the lower and upper sequences.

6. An area of more rapid subsidence to the east of Lake Lefroy lacks conglomerates and is fringed by ' highs ' oriented west of north and northeast.

Subsequent mapping in the area of the Kalgoorlie and Kurnalpi Sheets indicated that the conglomerates are not present west and northwest of Coolgardie but that they extend to the northeast to Yarri and beyond. In the south of the Kurnalpi Sheet area these conglomerates pass laterally into a succession of metamorphosed greywacke and schist. As a simplification, it can be said that the conglomerates in this region are present at two seaparate horizons. The lower horizon, which occurs at Lake Rebecca south of Pinjin, is characterized mainly by felsic lavas. The lavas are overlain by and interfinger with conglomerates of the oligomictic, ' porphyry,' type. The higher and more widespread horizon is recognized by the association in some places of greywacke and polymictic conglomerates and in others of oligomictic conglomerates and flows and sills of felsic rocks.

ORIGIN

Several different theories of origin have been proposed for the conglomerates. After Honman's work at Mt. Jackson and south of Kalgoorlie, the conglomerate at Kurrawang was generally thought to be a basal conglomerate lying unconformably on older rocks. The earlier opinion that the conglomerate beds were part of the Archaean succession was later revived, and it has been confirmed by all subsequent work. Most of the conglomerates away from Kurrawang are thought to be part of the main sedimentary succession. It is pointed out by Mclaren and Thomson that the beds at Kurrawang have been ' claimed by glaciologists as products of ice action', but that they considered them to be riverine deposits. A glacial origin was also suggested by Mawson (1949) for the conglomerates at Kanowna.

The oligomictic conglomerates were attributed by Gibson to brecciation by shearing before final crystallization of an intrusive igneous rock. This concept is comparable to that of Trendall's, who considers that ' it is possible that such greywackes may be the ultimate detrital product of bulk flow of porphyry with or without admixed terrigenous detritus '.

Maitland pointed out that there are ' conglomerates of undoubtedly sedimentary origin at Kanowna', and this is how they were described by Blatchford and Jutson.

An outcrop was described by Honman as ' massive porphyry containing rounded and angular inclusions of porphyry in a porphyritic ground mass ' and he considered that ' the massive porphyry bands have been derived almost *in situ* by subcrustal fusion from rocks similar to the metamorphic schists adjoining'. Almost fifty years later, the idea that the conglomerates are changed into porphyries became popular. This viewpoint is reported by Sofoulis. The idea that these conglomerates have been ' porphyritized ' was not favoured by Trendall. We have not recognized any ' porphyroids ' with porphyroblastic feldspars, although G. J. H. McCall and W. R. O'Beirne of the University of Western Australia inform us that they have evidence supporting ' porphyritization ' near Widgiemooltha. A porphyry, now known to be unconformably overlain by a conglomerate to the east of Coolgardie, was attributed by McMath to granitization of the conglomerate.

CONCLUSIONS

The Archaean succession containing the conglomerates consists of greywacke beds interfingering with mafic and felsic extrusive rocks and intruded by concordant and discordant bodies of ultramafic, mafic, and felsic rocks (including granite). There is more than one horizon with conglomerates. Where polymictic conglomerates are common, there are no felsic rocks in the nearby and immediately underlying rocks. On the other hand, oligomictic conglomerates are invariably closely associated with flows and sills of felsic rocks. The oligomictic conglomerates have their provenance in these felsic rocks. The zone of conglomerates extends for at least 300 miles from Southern Cross and Norseman to north of Laverton, and where best developed is about 100 miles across. The zone was a ' positive ' area throughout the formation of the upper part of the Archaean sequence. Emergence of areas within this zone is indicated by conglomerate and breccia, unconformities, basalt with vesicles, and rhyolite agglomerate. The geography of the time can be pictured as a chain of volcanic islands which was oriented northeast. This palaeogeographic trend is oblique to that of the main fold axes in the region.

ACKNOWLEDGEMENTS

Helpful discussions with Mr. H. A. Ellis, former Government Geologist ; Dr. G. J. H. McCall, and Messrs. W. R. O'Beirne and Y. Glikson-Aran of the University of Western Australia ; and Mr. N. Pratt of Australian Selection Trusts, are gratefully acknowledged.

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STRUCTURAL LAYERING IN THE PRECAMBRIAN OF THE MUSGRAVE BLOCK, WESTERN AUSTRALIA

by R. C. Horwitz, J. L. Daniels, and M. J. B. Kriewaldt

ABSTRACT

Near the Western Australian border, between latitudes 25° and 27° S., sedimentary rocks and volcanic flows, dated at about 1,100 m.y., unconformably overlie porphyry, granulite, rapakivi (pyterlite) granite, and a granite gneiss sheet. At rock unit contacts, the sequence is also intruded by another granite sheet and by the Giles Complex which includes four main gabbro sheets.

Prior to the intrusion of the Giles Complex, there were at least two periods of tectonism with metamorphism, including one older and another younger than the unconformity. Near the W.A. border, north of latitude 25° 30′ the Giles Complex is absent and the granites are greatly reduced. A complex sequence of events resulted in a layered structure which was folded before the end of the Precambrian on axes trending west-northwest, and with recumbent folds in the north. The Giles Discontinuity, regarded as a zone of transcurrent faulting, transects the fold area diagonally from the northeast. The sequence is followed by basalt at MacDougall Bluff and by dolerite dykes, which are considered to pre-date late Proterozoic glacial rocks elsewhere. The Giles Complex is considered to be late Proterozoic, although part could be older than this.

INTRODUCTION

The assemblage of Precambrian plutonic, metasedimentary, sedimentary, and volcanic rocks that straddles the 26th parallel near the Western Australian border and extends into the southwest of the Northern Territory and the northwest of South Australia, has been called both the Pitjentara Shield (Chewings, 1935 ; Ellis, 1937) and the Musgrave Block (Hills, 1965 ; Thomson, 1966).

These rocks form a basement to the late Precambrian and Phanerozoic rocks of the southern part of the Amadeus Basin (see Horwitz and Daniels, 1967), and contain the Giles Complex, named by Sprigg and Wilson (1959). This complex is composed of a number of plutons of basic rocks with associated ultrabasic and acid rocks.

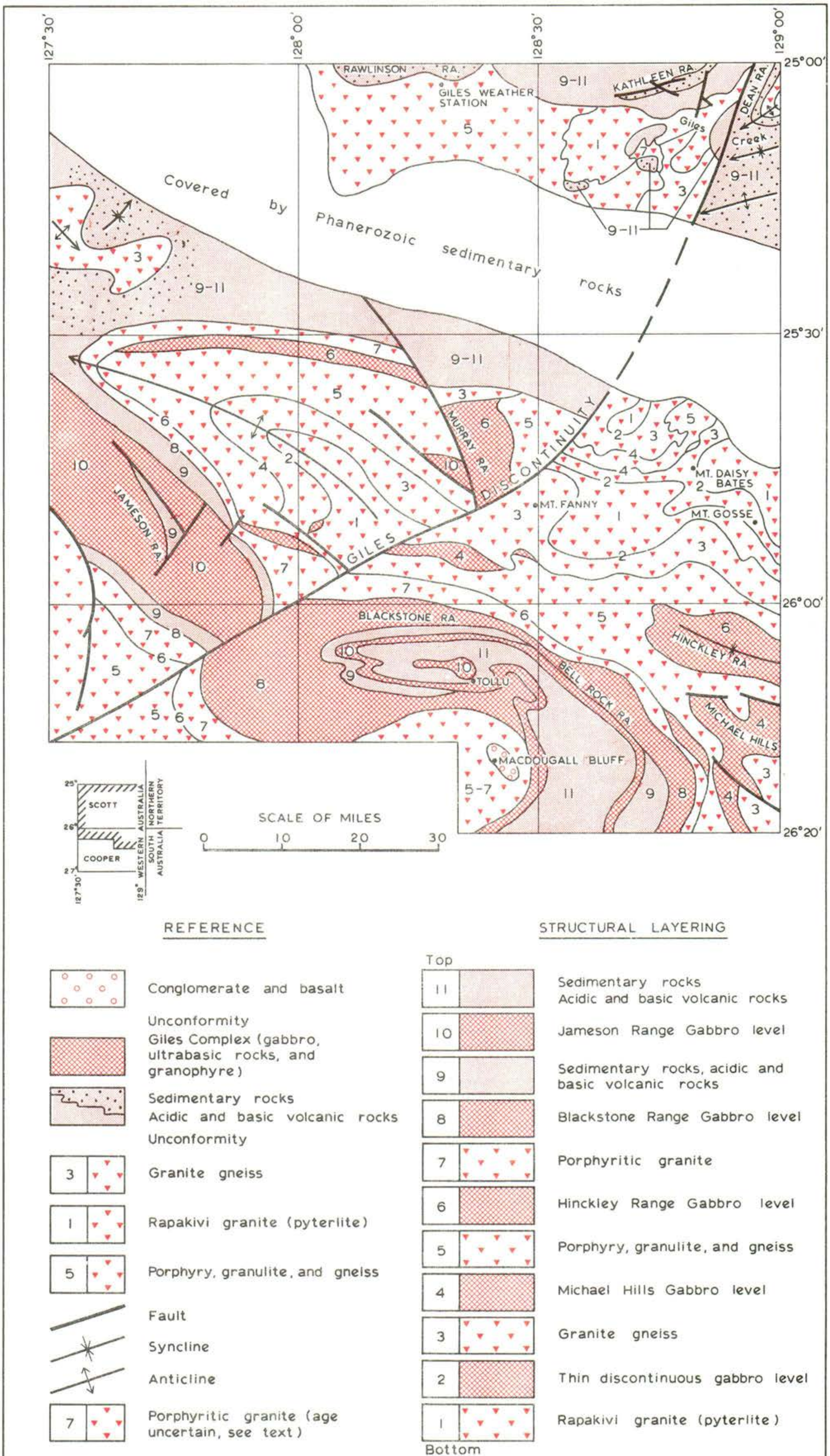
Mapping of the Scott and Cooper 1:250,000 Sheet areas, which cover a portion of the Western Australian part of the Musgrave Block, has revealed several features. The block is composed of at least two unconformable sequences, both intruded in parts by granite. The Giles Complex is not a single sheet, disrupted by folding and shearing, but several intrusions, each with its own characteristics (Daniels, 1967). There are several granites, two of which occur in sheets. The different sheets of the Giles Complex, and the granites, have intruded certain horizons ; the most favourable horizons are usually the contacts, or deduced contacts, of the different country rock units. These plutonic sheets are confined to the southern part of the area, although the sheets of granite extend further north than the sheets of the Giles Complex. Dolerite dykes which cut all other units of the Musgrave Block, are also restricted to the south, having the same regional distribution as the sheets of the Giles Complex. The distribution of igneous rocks defines an igneous province.

STRUCTURAL LAYERING

The recognition of the different sheets of the Giles Complex, of the various granites in the region, and of the stratigraphy of the host rocks has led to the recognition of a folded structural layering of rocks in this part of the Musgrave Block.

This layering is most clearly seen between the Michael Hills and Bell Rock Range where the structural succession is :

Top. Acidic and basic volcanic rocks
Gabbro
Porphyritic granite
Gabbro
Granulite
Gabbro
Granite gneiss



INTERPRETATION OF THE MUSGRAVE BLOCK IN WESTERN AUSTRALIA

The volcanic rocks, at the top of this succession, are an assemblage of separate acidic and basic volcanic flows. In the Jameson Range region the volcanic rocks are regionally metamorphosed and a gabbro is developed some distance above their base.

Between Hinckley Range and Mt. Gosse, a poorly developed, discontinuous gabbro horizon is present in the basal part of the granite gneiss ; the underlying granite is a rapakivi (pyterlite, see Horwitz and Daniels, 1967).

Combining these sequences with other local sequences and using the names of the gabbro levels given by Daniels (1967) the following structural layering is obtained :

Top. 11. Acidic and basic volcanic rocks
10. Jameson Range Gabbro level
9. Acidic and basic volcanic rocks
8. Blackstone Range Gabbro level
7. Porphyritic granite level
6. Hinckley Range Gabbro level
5. Granulite, gneiss and porphyry
4. Michael Hills Gabbro level
3. Granite gneiss level
2. Thin discontinuous gabbro level
1. Rapakivi granite

CHRONOLOGY

Within the zone containing igneous sheets, gabbro is not developed along the total length of each contact but forms localized lens-shaped bodies up to 21,000 feet thick (Jameson Range Gabbro) and 68 miles long (Blackstone Range Gabbro). In the south end of the Bell Rock Range, no volcanic rocks separate the Blackstone Range Gabbro (level 8) from the Jameson Range Gabbro (level 10). The latter, which is in some areas a granophyre, is rich in xenoliths of the volcanic rocks. Within the zone containing igneous sheets, the granite sheets of levels 3 and 7 are present throughout.

The structural succession is not in chronological sequence. The units of the different levels, separated by gabbro intrusions, are usually of a single rock type, as set out in the table ; however, the granite gneiss contains rafts of granulite and the main granulite (level 5) contains pods of granite gneiss.

In the northern part of the Scott Sheet area, in the Kathleen Range, volcanic flows are overlain by a thick succession of sandstones and phyllites. There, and throughout the region north of Giles Creek, these acidic and basic volcanic flows rest unconformably on the rapakivi granite, and south of the Giles Creek, pods of porphyritic granite have intruded the contact.

At Giles Weather Station a porphyry several thousand feet thick separates the rapakivi granite from the unconformity ; and in the general locality of Mt. Daisy Bates and Mt. Gosse, granite gneiss occurs between the rapakivi granite and a metamorphosed and sheared porphyry which can be traced into granulite at Mt. Fanny. The porphyry of the Giles region is thus equated with the granulite and gneiss (level 5) and the granite gneiss is thus believed to have intruded at the contact between levels 1 and 5. It is thought that the rapakivi granite is intrusive into the porphyry. In the Murray Range, an outlier of acidic and basic volcanic rocks rests on eroded granite gneiss.

The relative age of the gabbro sheets is discussed by Daniels (1967) who considers that they are genetically related. Their relationship to the porphyritic granite has been observed south of the Hinckley Range where it is intruded and assimilated by gabbro.

There have been at least two periods of metamorphism including one older and another younger than the unconformity.

The following chronological order of events in the region is proposed :

A. the oldest rocks are the porphyry and granulites of level 5

B. intrusion of rapakivi granite (level 1)

C. regional metamorphism more intense towards the south

D. intrusion of granite (gneiss of level 3)

E. erosion, followed by volcanic flows and deposition of sediments (levels 9 and 11)

F. regional metamorphism

G. intrusion of the Giles Complex (levels 2, 4, 6, 8, and 10).

It is not known whether all the porphyritic granite is of the one age. At Giles Creek, porphyritic granite is intrusive into rocks of levels 9 and 11, and this granite is thus younger than event ' E '. South of Mt. Hinckley a porphyritic granite is intrusive into granulite of level 5, and is itself intruded by gabbro of level 6. It thus was formed before event ' G ' and after event ' C '; it is considered to be younger than event ' D '. Because it is not known to have intruded rocks of levels 9 and 11 south of the Blackstone Range, the porphyritic granite is possibly older than the unconformity ; that is, older than event ' E '. Regardless of age, the structural position of the porphyritic granite at level 7 is clear.

STRUCTURE

The structural layering has been used to construct a tectonic interpretation of the area. It was found necessary to invoke a northeasterly trending discontinuity running diagonally across the region. It is proposed to call this the Giles Discontinuity and it is thought to be a zone of transcurrent faulting. This discontinuity is supported by contrasting structural details, metamorphism and lithology on either side of the line, and by its continuation to the north as a zone of faults which have been mapped by Wells and others (1962).

The overall structure is that of a series of west-northwest trending anticlines and synclines. In the northern part of the area, these folds are recumbent to the south-southwest and dragfolds on the limbs are recumbent, or strongly overturned, to the west-northwest. These recumbent folds involve the unconformity between the volcanic rocks and the rapakivi granite. The recumbent structures were recognized and described by Forman and Hancock (1964).

AGE OF THE GILES COMPLEX

The Giles Complex is considered to be late Proterozoic, although part of it could be older than this. Volcanic flows at Tollu are about 1,100 million years old (Compston, pers. comm. 1965) ; they are intruded by part of the Giles Complex. Both the volcanic flows and the Giles Complex are cut by dolerite dykes. These dykes also cut an outcrop of basalt with a basal conglomerate at MacDougall Bluff which is known to be younger than the volcanic rocks of Tollu because it is unconformable on the eroded core of an anticline of the layered sequence. By comparison with adjoining areas, the dolerite dykes are considered to pre-date late Proterozoic glacial rocks.

The Giles Complex is thus older than the MacDougall Bluff rocks, the dolerite dykes, and (by comparison) the late Proterozoic glacial rocks ; and at least part of it is younger than 1,100 m.y.

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PROVISIONAL SUBDIVISIONS OF THE PRECAMBRIAN IN WESTERN AUSTRALIA, 1966

Compiled by R. C. Horwitz

The accompanying chart (Plate 27) of Provisional Subdivisions of the Precambrian in Western Australia is a revision of that published in the 1965 Annual Report.

Geological Survey mapping, and age determinations carried out at the Australian National University under the supervision of Dr. W. Compston, have added more information to this revision.

The boundaries of the subdivisions of the Precambrian have been amended to fit the revision of these boundaries as proposed by the Geological Survey of Canada (Stockwell and Williams, 1964). The top of the Archaean is placed at 2,400 m.y., the top of the Lower Proterozoic is set at 1,640 m.y., and the top of the Middle Proterozoic subdivision at 880 m.y. The Middle Proterozoic is divided at 1,280 m.y.

The chart emphasizes, in Western Australia, the following grouping of ages : In the Archaean, sedimentation and vulcanism are followed by granite intrusion at about 3,000 m.y. in some areas and at about 2,600 m.y. in other areas. In the Proterozoic, metamorphism followed by granite intrusion occurs at about 1,800 m.y. and at about 1,000 m.y. Work undertaken and in progress indicates that the igneous and metamorphic events, in the Proterozoic, appear to be spatially related to aspects of the previous palaeogeography while they initiate vulcanism which is preserved according to an aspect of a new palaeogeography.

The igneous events at about 2,600 m.y., 1,800 m.y., and 1,000 m.y. equate with the Kenoran, the Hudsonian, and the Grenville orogenies in the Canadian subdivisions of the Precambrian, provided that the ages of these orogenies are adjusted to the constants used at the Australian National University ; a problem outlined *in* Turek (1966, p. 29).

It is thus concluded that the relationship between palaeogeography and igneous activity is a key to an understanding of the world distribution of the Precambrian.

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SUBDIVISION OF THE GILES COMPLEX, CENTRAL AUSTRALIA

by J. L. Daniels

ABSTRACT

The Giles Complex of Central Australia is a late Proterozoic series of basic masses intrusive into granulites, granites, and mixed volcanic rocks. Most of the basic rocks of the complex display abundant igneous banding features. Among these, cross-banding is locally common and the directions of the currents responsible (probably returning cooler convection currents overturned at the top and outer margins of a convection cell) have been measured and used to subdivide the complex into four major, physically unconnected, sheet-form bodies. These are :

Jameson Range Gabbro
Blackstone Range Gabbro
Hinckley Range Gabbro
Michael Hills Gabbro

Probably all the basic sheets are genetically related, but whether they are temporally distinct remains to be determined in detail. Each sheet displays its own field characteristics as well as strong differences in petrography.

As with many similar associations in different parts of the world, the intrusions have been emplaced in country rocks which had already undergone major intense deformation and metamorphism. Subsequent to emplacement the area was folded into broad anticlines and synclines with wave lengths of approximately 10 miles.

INTRODUCTION

The late Precambrian Giles Complex is in central Australia astride the boundary between Western Australia and South Australia. It consists of a number of basic plutonic masses with associated ultrabasic and acid differentiates which crop out intermittently as a series of monadnocks in sandplain country. The complex has an overall east-west elongation and extends from the Jameson Range in Western Australia to approximately 100 miles east of Mt. Davies in South Australia, a distance of 210 miles. The maximum width of the complex is about 80 miles. The area of the province of the Giles Complex is not known with certainty, but could be between 7,500 square miles and 8,000 square miles.

This report is based largely on field work during 1966 and concerns the portion of the Giles Complex in the Scott and Cooper 4-mile Sheet areas of Western Australia.

Rocks of the complex intrude or are associated with a sequence of charnockites, granulites, acid and basic gneisses, and porphyritic acid and basic lavas. Porphyritic granite is also known in the area. The age of these rocks in relation to the Giles Complex is not known with certainty, but most are believed to be older (Horwitz and others, 1967).

On the whole the basic members of the complex are well banded. It is assumed that this banding developed on a slight slope of no more than a few degrees. As banding dips of between 45° and 90° are common throughout the area it is concluded that the complex was folded after emplacement and solidification. Despite the strong folding, rocks of the complex do not show regional metamorphic effects. Some of the gabbroic rocks of Jameson Range show widespread shearing, but this does not appear to have affected the composition of the constituent minerals and is purely a textural readjustment. The original banding and minor structures are still recognizable.

No direct isotopic age determinations have yet been undertaken on the Giles Complex. It has been referred to as Archaean, but recent work by the Geological Survey of Western Australia has shown that it is intrusive into acid and basic volcanic rocks of the Tollu area. These have been dated as 1,100 million years old (Compston *in* Horwitz and Daniels, 1967).

DESCRIPTION OF THE COMPLEX

Before describing the field characteristics of the individual basic and ultrabasic masses it is necessary to determine whether they represent dismembered parts of a once continuous lopolith, as suggested by Sprigg and Wilson (1959) or whether several discrete bodies are represented.

Primary igneous banding features are abundant in the majority of these monadnocks. Some of these have been described by Nesbitt and Talbot (1966) who also described some sedimentary-type structures. In addition to those described, abundant examples of cross-banding were found (Plate 28). These were studied in some detail and it was found possible to use the results to subdivide the complex.

It is postulated that cross-banding in basic igneous rocks is produced by a sedimentary process acting in a crystallising magma and is completely analogous to the production of cross-bedding in sedimentary rocks. The currents responsible for the cross-banding in the basic igneous rocks would be the returning, cooler convection currents having overturned at the top and outer margins of the intrusion.

With this in mind, the orientation of the cross-banding will give not only the local direction of the bottom convection currents, but also a regional picture, useful with or without additional geological data, for determining:

1. the number and locality of the original convection cells.

2. the original slopes of the chamber floor and hence the shape of the bottom of the intrusion.

3. the centre of the keel area of an intrusion.

Current directions, measured at a number of localities over the whole of the complex in W.A. are plotted on the accompanying map (Plate 30).

It will be seen that the current directions for the gabbroic rocks in the Jameson Range—Mt. Elliot area are fairly constant with trends to the north and northwest. Two measurements of currents from the north-northeast and northeast are noted. However, in this area, the overall picture is one of bottom convection currents trending in a northwesterly direction indicating that the base of this mass was planar and sloped to the northwest with minor variations. The centre or deepest part of the intrusion is assumed to lie somewhere to the northwest probably at a great depth.

This pattern is completely different from that provided by a combination of current directions taken from the Cavenagh Range, Blackstone Range, and Bell Rock Range. In this combination, although there is a great variation in current direction, the overall pattern is simple; that is, currents converging on a broad area about 8 miles south of Tollu.

The configuration of the current directions suggests that the Cavenagh Range, Blackstone Range, and Bell Rock Range are part of the same sheet which was originally basin shaped and perhaps somewhat elongated in a north-northwest direction.

Current directions in the gabbroic rocks of Michael Hills are by no means simple and indicate that the action of possibly three convection cells may be represented in what was a continuous mass. One of these cells occupied the northwest portion of the body, another lies at least 8 miles to the east-southeast and the third was located in the southern part of the exposed portion of the intrusion.

This pattern suggests two possibilities: within the original sheet there were at least three basin-shaped depressions, or the original sheet was horizontal and three independent convection cells developed within.

No current directions are available from the gabbro forming a large part of the portion of Hinckley Range in Western Australia as this area has not been studied in detail. In South Australia, approximately 3 miles northwest of Mt. Davies camp, cross-banding is locally well developed in the extension of the range. It is occasionally seen on Mt. Davies, which is probably the continuation of the gabbro of Hinckley Range. Not enough readings were made to produce a coherent picture.

The Giles Complex can therefore be subdivided into a number of separate bodies or units, which have fairly simple convection current characteristics. Their internal stratigraphy and structural position (see especially the Bell Rock Range, Hinckley Range, and Michael Hills region) confirm that these units are discrete bodies and not just dismembered remnants of one large sheet with numerous convection cells.

All the information available shows that there are four major sheets involved in the Giles Complex in Western Australia. These have been named and in order of increasing structural depth are:

10. Jameson Range Gabbro
8. Blackstone Range Gabbro
6. Hinckley Range Gabbro
4. Michael Hills Gabbro

The numbers before each gabbro refer to levels in the total structural sequence of the area which has been described elsewhere (Horwitz and others, 1967). These levels, even where gabbro is missing or poorly developed, can be traced and extrapolated throughout the whole region. The inset in Plate 30 shows the structural interpretation of the area.

DESCRIPTION OF INDIVIDUAL SHEETS

The following descriptions are based largely on fieldwork supplemented by a preliminary examination of some thin-sections. Figure 13 shows selected sections through the four major bodies with the major subdivisions for three of them. The section thicknesses were measured from aerial photographs using dips measured in the field. The subdivisions adopted here are generally obvious in the field, though with the examination of more thin-sections, or those available in detail, modification of these zones may later be necessary.

Except where used in detailed petrographic descriptions the terms gabbro or gabbroic rocks are used in a general sense to include all rock types of the gabbro clan.

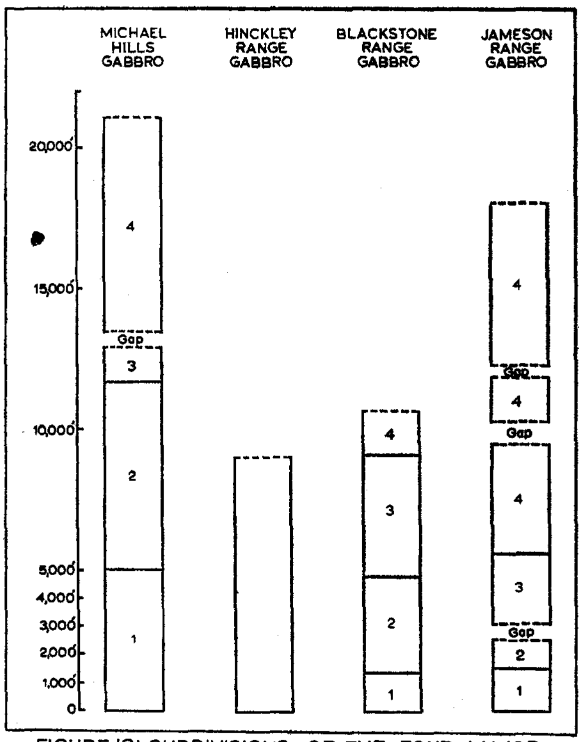

FIGURE 13: SUBDIVISIONS OF THE FOUR MAJOR SHEETS OF THE GILES COMPLEX

Michael Hills Gabbro

The intrusion has been provisionally subdivided into four major zones which together are over 21,000 feet thick. Thicknesses of the individual zones are given in Figure 13.

Zone 1. The basal zone is characterised by the presence of banded leucocratic gabbroic rocks, anorthosites, and interbanded pyroxenites. Igneous banding is well developed on all scales but cross-banding is rare.

Below the base of this zone, granite gneisses and some granulites are observed and within approximately 200 feet of the main contact they have been intruded by several basic sills. These sills have connected the country rock to contact hornfels and are themselves composed of medium to fine-grained hypersthene gabbro carrying strongly antiperthitic, vaguely twinned, plagioclase (An_{49}).

Hypersthene gabbro also forms most of the basal zone. It consists of coarse hypersthene and clinopyroxene, both with exsolution lamellae of one in the other. The orthopyroxene shows schiller structure and moderate pleochroism. The clinopyroxene is commonly multiply twinned. The plagioclase, labradorite, is frequently poorly twinned. Twinning according to the albite law is usually almost suppressed. Pericline and carlsbad twins are not uncommon. Accessories include iron ore and red-brown biotite. Most of the constituent grains have been stressed with the production of bent and fractured crystals and undulose extinction in the feldspar. Some examples have been granulated and appear now as a fine-grained plagioclase mosaic with elongated mafic bands also generally granular. In the lowermost 1,000 feet of the zone antiperthitic plagioclase is abundant.

Interbanded pyroxenites are more common in the lower half of the zone. They are generally between 20 and 50 feet thick and consist of medium to coarse-grained hypersthene and clinopyroxene in approximately equal proportions. Some plagioclase (5%) is generally present as interstitial grains. The pyroxenes appear to be similar to those in the hypersthene gabbro.

Zone 2. The top of zone 1 is not well defined. In zone 2, however, no thick bands of pyroxenite occur and anorthosites are rare. The zone is well banded and the main rock type is a hypersthene gabbro very similar to that of zone 1, and need not be described further. Antiperthitic plagioclase is present in the upper portion of the zone.

Zone 3. The zone is characterized by thin, well-defined banding and fairly fresh appearance in contrast to the ' crusty ' weathering of the two lower zones. Gravity differentiated bands (' graded beds ') and cross-banding are common. The rock is a hypersthene gabbro with rare antiperthite and is similar to that of zones 1 and 2. Shearing has affected the rock to a minor extent.

In zones 1, 2, and 3 a conspicuous fine-grained rock is apparently transgressive to the banding, but in places forms ' xenoliths ' in the coarser banded gabbros. It is itself a hypersthene gabbro with similar accessories to the main gabbro.

Zone 4. The uppermost zone is banded, weathers black and encloses large sheets of granitic gneiss, which have been partly stoped and assimilated. Hypersthene gabbro with opaque accessory minerals and a red-brown biotite is the commonest rock type. Aligned quartz-feldspar streaks are present in the gabbro. These are discussed at greater length in the section concerning assimilation.

Intrusive into what appears to be the upper part of zone 4 are two apparently cross-cutting rock types. One consists of pegmatitic gabbro, the other is pyroxenite.

The pegmatitic rock (troctolite) is fresh, unsheared and so completely different mineralogically from the rest of the Michael Hills Gabbro that it most probably represents a younger minor intrusion unconnected with the Michael Hills gabbro sheet. It may represent the feeder for a basic sheet at a higher structural level.

The pegmatitic gabbro consists predominantly of coarse olivine and plagioclase (approx. An_{50}). Crystals between 1 and 2 inches are common while crystals up to 4 inches long have been noted. Reaction rims around the olivine are abundant and consist of an inner rim of hypersthene frequently intergrown with vermicular green spinel. Outward is a further zone of cloudy-green aspect made of an extremely fine vermicular intergrowth of a high relief green mineral (? spinel) and a colourless mineral (? feldspar). A partial rim and scattered crystals of a slightly pleochroic pale-brown hornblende is occasionally present. It may be partly intergrown with vermicular green spinel and, when present, the rim occurs interposed between the other two reaction rims. A thin peripheral band of very strong zoning is noted on the plagioclase in contact with the reaction rims. Accessory minerals in the whole rock include magnetite and pleonaste grains.

Another practically circular mass to the west of the pegmatitic gabbro is also probably a late intrusive. However, it consists of ortho- and clinopyroxene in approximately equal amounts and is probably genetically related to the Michael Hills Gabbro.

The two younger intrusions are near the centre of an arc formed by zone 4 of the gabbro. In this zone the orientation of quartz-feldspar ' blebs ' in the gabbro was measured. They tend to converge on this same area and may represent flow structures spreading out from a centre. The focal point, therefore appears to have been a centre of repeated activity.

Summary of Michael Hills Gabbro. The Michael Hills gabbroic sheet is a thick well-banded mass of hypersthene gabbro devoid of olivine. The hypersthene is distinctive, being fairly strongly pleochroic and carrying abundant schiller inclusions. It occurs in almost equal or lesser amounts than the accompanying clinopyroxene. Antiperthitic inclusions in the plagioclase are abundant at some levels and these, together with field evidence, suggest that a large amount of granitic material has been assimilated by the gabbro, and presumably drastically changed its original composition. In the lowest zones frequent pyroxenite bands are encountered. Throughout the intrusion the effects of stress are noted to a greater or lesser degree. Two younger intrusions cut the Michael Hills sheet. One is a pyroxenite, possibly genetically related to the main mass. The other is pegmatitic troctolite, probably younger than the Michael Hills sheet, and possibly a feeder for a gabbroic sheet at a higher structural level.

Hinckley Range Gabbro

Little work has been done on the Hinckley Range Gabbro. The total thickness was not measured during the present study but is given by Nesbitt and Talbot (1966) as approximately 9,000 feet. The gabbro occupies a syncline whose north-northwest axis runs through the length of the Hinckley Range. The southern limb thins out to the west (Plate 30). Two miles east of the point where the mass thins out, the gabbro has thickened to just over 3,600 feet while approximately 9 miles further east it reaches its maximum thickness. Little or no igneous banding is visible until the thickness reaches approximately 3,000 feet. It appears, therefore, that a minimum thickness of approximately 3,000 feet is necessary before igneous banding will develop in the Hinckley Range mass. Cross-banding structures appear to require greater thicknesses as they were not seen in the first banded rocks but are well developed in the thicker part of the section approximately 3 miles northwest of Mt. Davies camp in South Australia.

At much of the lower contact, and above the body, there is a contaminated, fine-grained basic igneous rock forming thick masses and transgressive sheets in the granitic and granulitic country rock, which it has assimilated. Remnant sheets of country rock are too small to depict on the accompanying map. The basic material carries characteristic, quartz-feldspar ' blebs ' and schlieren similar to that seen in the contaminated gabbros of the Michael Hills. Antiperthite is common. The main rock type in the contaminated zone is a fine-grained hypersthene gabbro.

The mass has not been subdivided. Rock types present include olivine-norite and olivine-hypersthene gabbro. Accessory minerals include iron ore, pleonaste, and red-brown biotite. Chromite has been found near Wingellina.

On the northern side of the syncline near Wingellina ultrabasic rocks have been intruded probably along shear planes. Fresh samples are not available but the original rock was probably a dunite or serpentinite. Alteration has taken place and produced nickeliferous ochre, a lightweight, pale brown powdery rock of possible economic value for its nickel content.

Blackstone Range Gabbro

One section through the gabbro was measured in the Blackstone Range, approximately 12 miles east of the western extremity of the range. Here the sheet is approximately 11,000 feet thick and divisible into four main units overlying sheared and possibly contaminated basic igneous material with a minimum thickness of 3,000 feet.

Zone 1. The basal zone of the sheet is coarse-grained, shows poorly developed igneous banding and some development of a pegmatitic gabbro facies.

One specimen from this zone is a coarse-grained hypersthene troctolite with sub-ophitic texture. Accessories include iron ore, pleonaste, and red-brown biotite. The hypersthene is weakly pleochroic, shows well developed schiller structure and possesses abundant small rounded enclosures of clinopyroxene in optical continuity.

Zone 2. Fine igneous banding characterises zone 2. Gravity differentiated units are common and cross-banding is moderately abundant. One example of trough banding was noted.

The zone appears to be mineralogically composite. The lower third is composed of olivine-norite which also forms a thin horizon at the top. The rest of the zone is troctolite with rare accessory hypersthene.

Zone 3. This zone consists entirely of hypersthene troctolite with hypersthene present only in small amounts. The lower third is well banded, in contrast to the upper portion which is very poorly banded.

Zone 4. Mafic troctolite forms the uppermost zone. It is a dark-weathering rock, which in thin-section is seen to be composed of abundant fresh olivine forming a polyhedral mosaic with approximately 10% plagioclase and accessory clinopyroxene, orthopyroxene, iron ore, and red-brown biotite.

The main mass of Bell Rock Range is closely comparable with the Blackstone Range and is regarded as part of the same intrusion on a consideration of the cross-banding results. Rock types distinguished include troctolite (commonest), hypersthene troctolite, olivine gabbro, and poikilitic olivine-hypersthene gabbro near the base.

The smaller range of hills immediately southwest and flanking the main mass of Bell Rock Range is composed of gabbro with some amphibolite. Bands and dykes of granophyre are common. The gabbro consists of laths of dusty plagioclase with interstitial clinopyroxene and accessory iron ore and brown biotite. It is devoid of olivine.

No physical connection is seen with the Bell Rock Range mass and as the rock type and the associated rocks are so completely different from the Blackstone Range Gabbro it must be regarded as part of a gabbro forming a higher structural level. In texture and mineralogy the gabbro is similar to gabbros immediately south of Tollu and 8 miles southeast of Tollu. These are intrusive into lavas and associated with granophyres.

Summary of Blackstone Range Gabbro. This intrusion is generally well banded and consists dominantly of olivine-bearing rocks with troctolite predominating.

Jameson Range Gabbro

Four main zones have been mapped in the Jameson Range sheet, together totalling more than 18,000 feet thick. The sheet is moderately well banded. Some shearing has affected the gabbroic rocks of Jameson Range itself, but the shearing has taken effect as a partial granulation of the minerals. No chemical change seems to have occurred and the primary igneous banding is not greatly affected.

Zone 1. In the field the basal zone is distinctive, being dark-weathering and glomeroporphyritic. The glomerocrysts are composed of plagioclase and weather out to give the rock a pock-marked appearance.

The zone is variable in composition. Generally, it is composed of dusty plagioclase laths with oscillatory zoning, in a groundmass of strongly pleochroic green hornblende. The latter frequently carries abundant, small, rounded quartz enclosures and some samples show relict clinopyroxene. Accessories include iron ore, partially replaced by sphene, and some red-brown biotite. One relatively unaltered sample shows poikilitic clinopyroxene, with rare relict olivine. The pyroxene is surrounded by abundant small laths of red-brown biotite. The associated plagioclase is a calcic labradorite with some laths strongly zoned and having oligoclase margins. The rock may be called an olivine gabbro.

Zone 2. Above the glomeroporphyritic gabbro is a zone of mafic rocks up to 1,000 feet thick. One sample from the zone carries titaniferous magnetite, brown hornblende, olivine, and clinopyroxene with traces of plagioclase and orthopyroxene. Another sample is a clinopyroxenite with traces of ore and plagioclase, but devoid of olivine.

The zone is continuous for several miles, but is poorly exposed on account of a development on laterite on its outcrop.

Zone 3. This zone forms the main part of the Jameson Range itself. It is a well banded zone and the rocks are fairly uniform in composition throughout, being almost entirely hypersthene troctolites with opaque accessories and red-brown biotite.

Zone 4. This zone is distinguished in the field by the presence of anorthosite and titaniferous magnetite bands. The main rock types include

Table 1

PARTIAL ANALYSES OF TITANIFEROUS AND VANADIFEROUS IRON ORES FROM THE GILES COMPLEX

(Analyses by Government Chemical Laboratories)

G.S.W.A. Spec. No.	523A	523B	523C	1245A	1245B	1245C	1255A	1255B	1236	1237	1261	1262	1266A	1266B	1266C
Fe_2O_3	55.4	62.6	62.4	15.6	12.7	16.4	51.3	59.1	56.9	54.7	67.3	63.0	62.5	65.3	65.5
FeO	15.7	10.1	14.8	24.4	25.7	28.4	11.3	12.3	10.8	12.6	6.75	8.06	11.0	7.68	6.80
TiO_2	18.7	17.4	12.3	13.6	17.3	15.2	26.2	18.2	21.0	17.2	15.9	20.9	18.9	19.6	19.5
MnO	0.23	0.25	0.29	0.30	0.34	0.29	0.24	0.28	0.31	0.28	0.21	0.07	0.08	0.11	0.10
SiO_2	1.69	1.55	1.31	24.1	23.1	19.9	1.82	1.04	1.33	3.62	1.70	1.36	1.63	1.75	1.58
Al_2O_3	4.02	3.51	5.41	6.26	5.22	7.35	4.95	5.13	4.06	4.47	4.53	2.39	2.35	2.45	2.69
P_2O_5	0.07	0.06	0.04	0.03	0.08	0.06	0.04	0.04	0.03	0.04	0.08	0.11	0.24	0.11	0.10
S	0.01	0.03	0.03	0.04	0.08	<0.01	0.05	0.03	0.02	0.03	0.03	0.02	0.06	0.02	0.09
V_2O_5	1.04	1.25	1.11	0.70	0.57	0.76	1.18	1.33	1.40	1.11	0.75	0.71	0.77	0.81	0.76
Cr_2O_3	0.06	0.07	0.08	<0.01	0.01	0.01	0.03	0.18	0.38	0.63	0.14	0.29	0.25	0.28	0.28
NiO	0.13	0.13	0.10	0.06	0.04	0.05	0.04	0.08	0.15	0.10	0.02	0.05	0.05	0.05	0.04
MgO	1.57	0.80	0.71	6.19	8.05	6.65	1.78	1.81	2.28	3.49	0.78	1.43	1.09	0.93	0.88
CaO	<0.01	<0.01	0.02	6.47	5.80	3.80	0.07	0.04	0.04	0.04	0.22	0.04	0.09	0.12	0.18

523A	Northeast end Bell Rock Range
523B	do. do. do.
523C	do. do. do.
1245A	Zone 2 of Jameson Range Gabbro
1245B	do. do. do.
1245C	do. do. do.
1255A	Lower part of zone 4 Jameson Range Gabbro
1255B	do. do. do. do.
1236	Finlay Range, part of Jameson Range Gabbro
1237	do. do. do. do. do.
1261	Upper part of zone 4 Jameson Range Gabbro
1262	do. do. do. do. do.
1266A	do. do. do. do. do.
1266B	do. do. do. do. do.
1266C	do. do. do. do. do.

hypersthene troctolite, troctolite, olivine gabbro, and hypersthene gabbro. Titaniferous magnetite bands increase in frequency and apparently also in thickness, in the upper half of the exposed part of zone 4. These are poorly exposed and frequently covered by laterite. No reliable estimate of tonnage can be given but it must be considerable. Two circular structures in the upper part of the zone are formed of banded titaniferous magnetite and are partly obscured by laterite. These appear as anomalous trends in the overall simple banding and may be diapiric structures.

Summary of Jameson Range Gabbro. This sheet is composed dominantly of hypersthene troctolite with a lower zone of olivine gabbro and upper levels with anorthosite and abundant titaniferous magnetite bands.

Contaminated rocks

The map shows large areas of a contaminated facies of the gabbroic rocks. These rocks are complex and are not yet fully understood. In large part they represent areas of country rock almost completely stoped and assimilated. In other areas they represent a border facies to the gabbros with or without evidence of assimilation.

In the most obvious examples the basic rock can be seen to have fragmented and assimilated granitic gneisses and granulites, to produce a dark, blue-grey, fine-grained rock with abundant quartzo-feldspathic ' blebs ' or schlieren (Plate 29). With more complete assimilation these blebs become very small, but remain highly distinctive especially on a weathered surface. They are generally composed of plagioclase, ortho- and clinopyroxene with variable quartz, microcline, cordierite, red-brown biotite, and opaques. The plagioclase is commonly antiperthitic as it is in some of the gabbros, especially those of the Michael Hills. In some gabbros cordierite and variable quantities of quartz are present.

The overall picture suggests that contamination is a major factor in the petrogenesis of the gabbros of the Giles Complex.

Minor gabbroic masses

The remainder of the isolated gabbroic masses have been satisfactorily placed within one of the four major gabbro levels with the exception of some gabbroic sheets to the northeast. These are thought to represent a discontinuous level in granitic gneisses.

Both stratigraphy and general petrographic type are useful in determining the structural level of any isolated gabbroic mass. The isolated gabbroic masses intrusive into the volcanic province around Tollu together form the highest level of intrusion and are probably part of the same sheet as the Jameson Range Gabbro. These isolated masses show general similarities in texture and a degree of saussuritisation and uralitisation are not encountered in the lower levels. Granophyres are frequently encountered, either as dykes or as a sheet-like top to the gabbro. The granophyres, forming the main mass of Skirmish Hill 17 miles south of Tollu and intrusive into quartz-feldspar porphyries, are probably part of this level.

ECONOMIC CONSIDERATIONS

Nickeliferous ochre is known on the north side of the Hinckley Range mass as an alteration product of dunite or serpentinite. Its total extent, depth, and grade are not known, but it is under investigation by Southwest Mining Co. Ltd. Small amounts of chrysoprase are known as thin veins in the ochre.

Titaniferous magnetite bands are abundant in the upper part of the Jameson Range Gabbro. The total amount must be large, but exposures are poor in that region. Partial analyses of some samples from this region and a thin band from the northwest corner of Bell Rock Range are given in Table 1. TiO_2 ranges from approximately 13% to 26%. V_2O_5 is also generally high ranging from 0·57% to 1·4%. Laterites are locally developed on some of the titaniferous magnetite bands.

A consideration of the bottom convection current directions determined from the cross-banding is of possible major importance for future prospecting. The currents responsible would probably have been most active in the early stages of cooling and could have concentrated early formed sulphides at the bottom of the intrusion. More detailed mapping of the current directions, together with fabric analyses of the gabbros, would almost certainly locate areas worthy of further study by geophysical methods.

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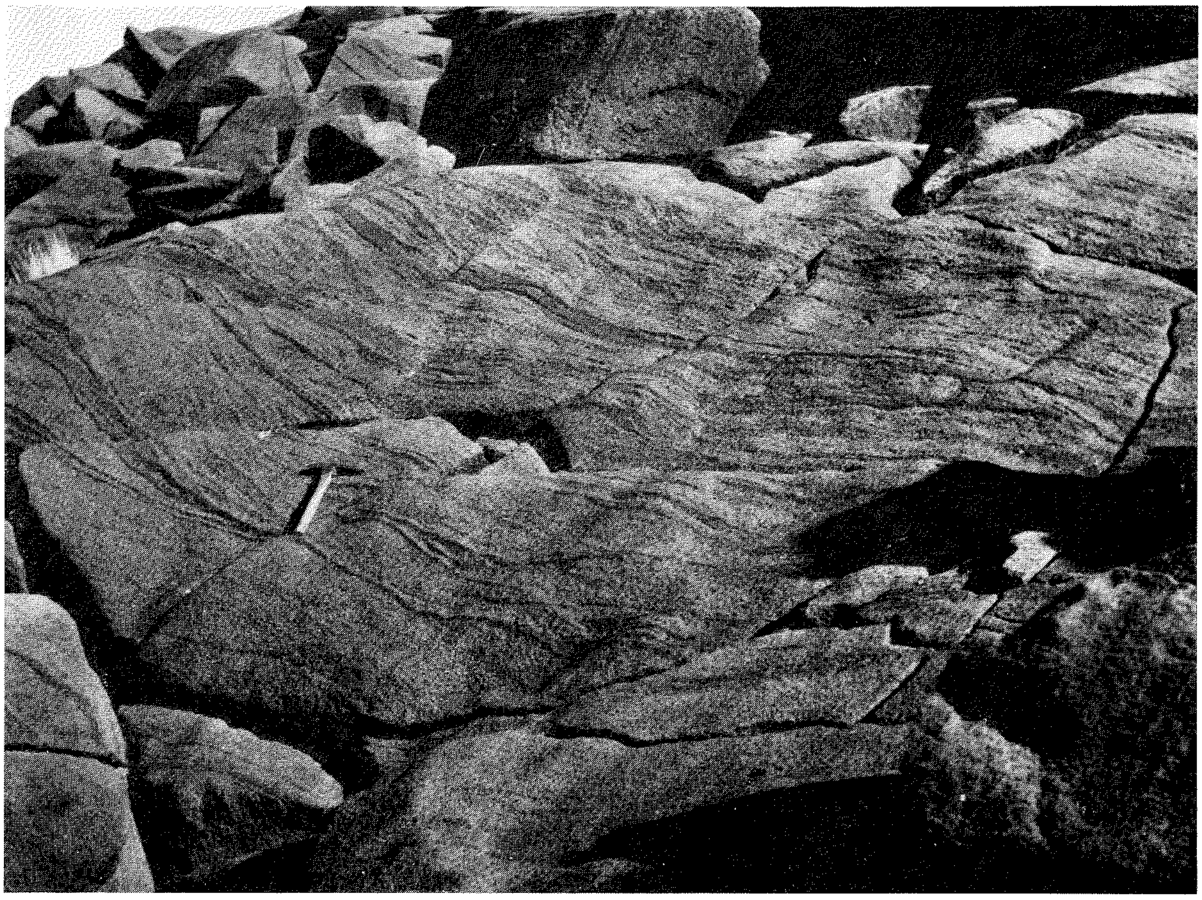
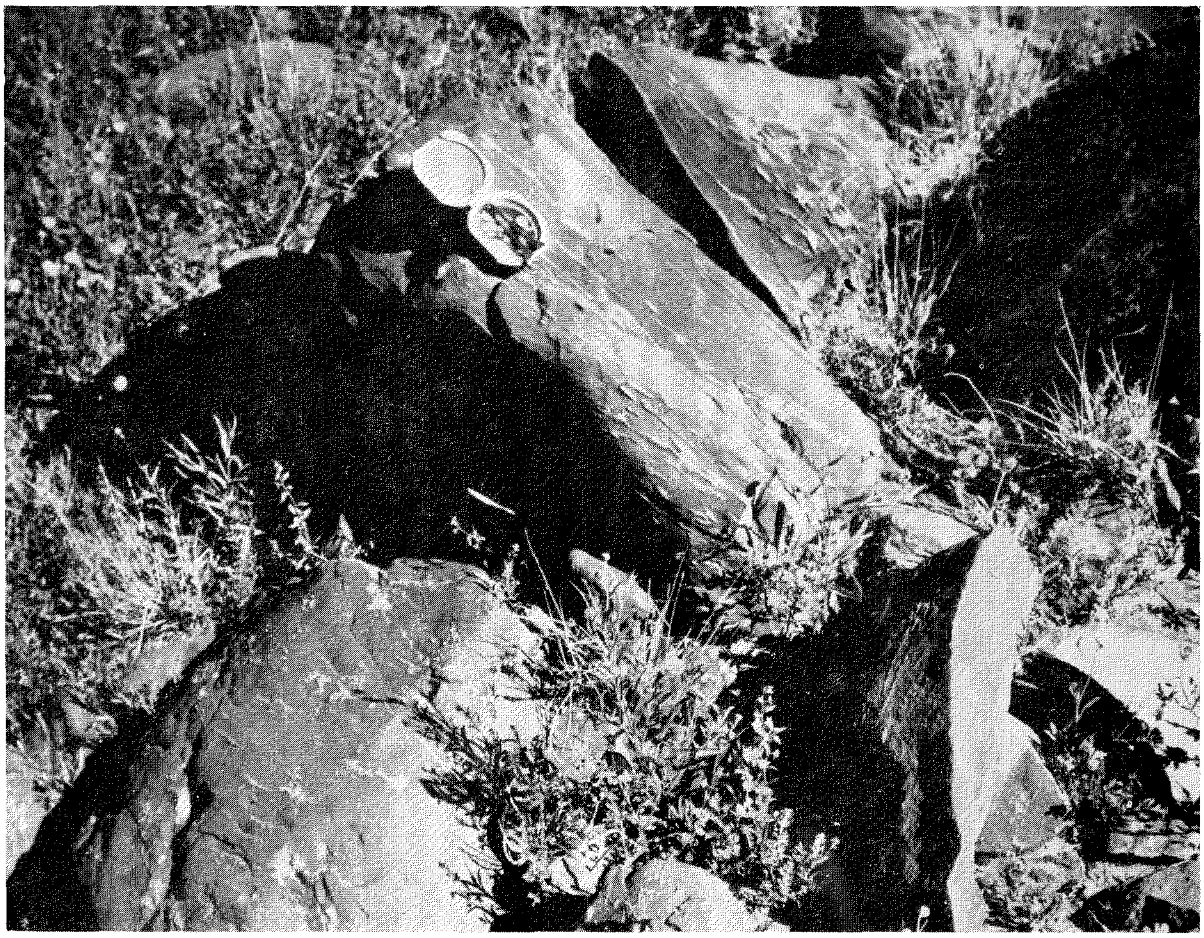
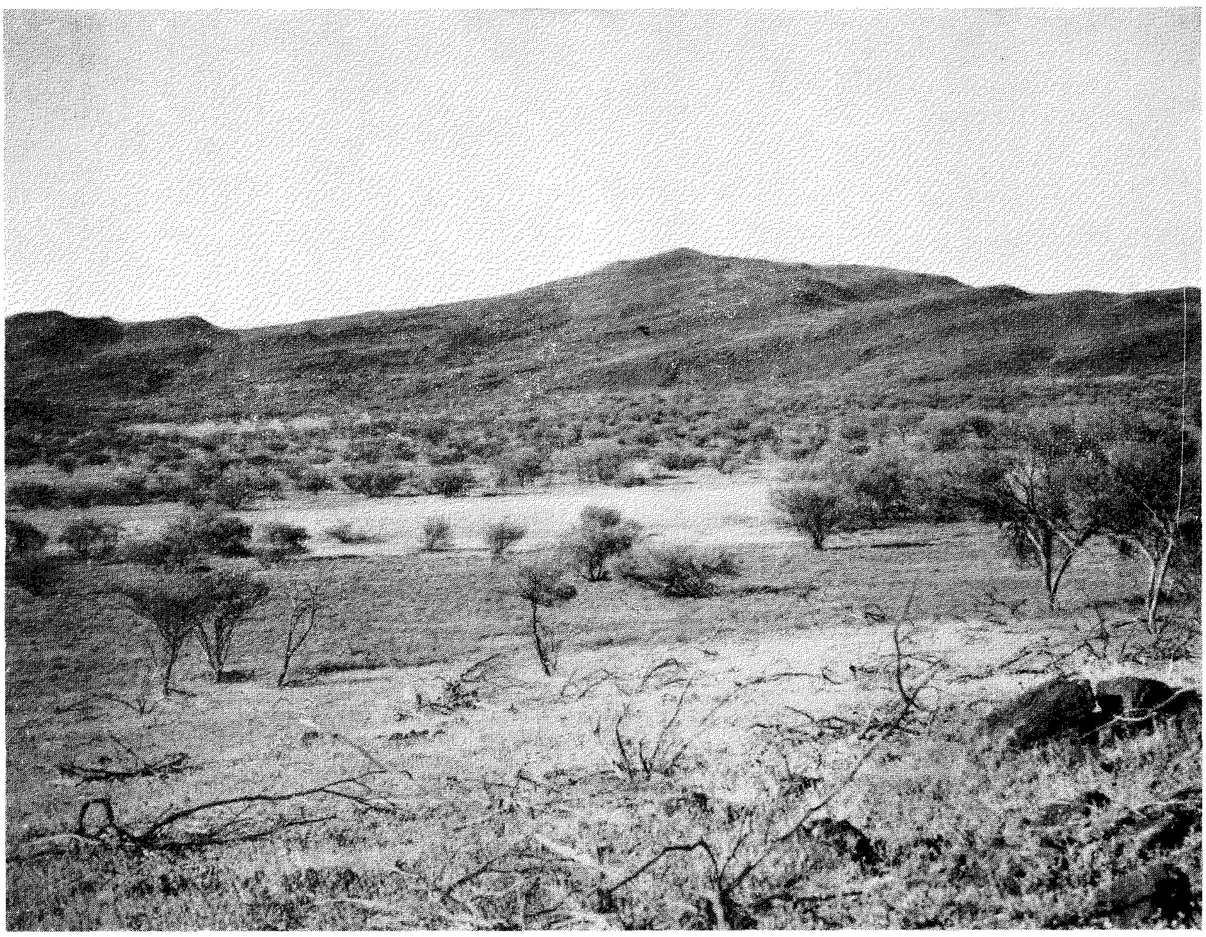


A—Abundant cross-banded units in steeply dipping gabbro. Northwest end of Bell Rock Range ; F 1160.

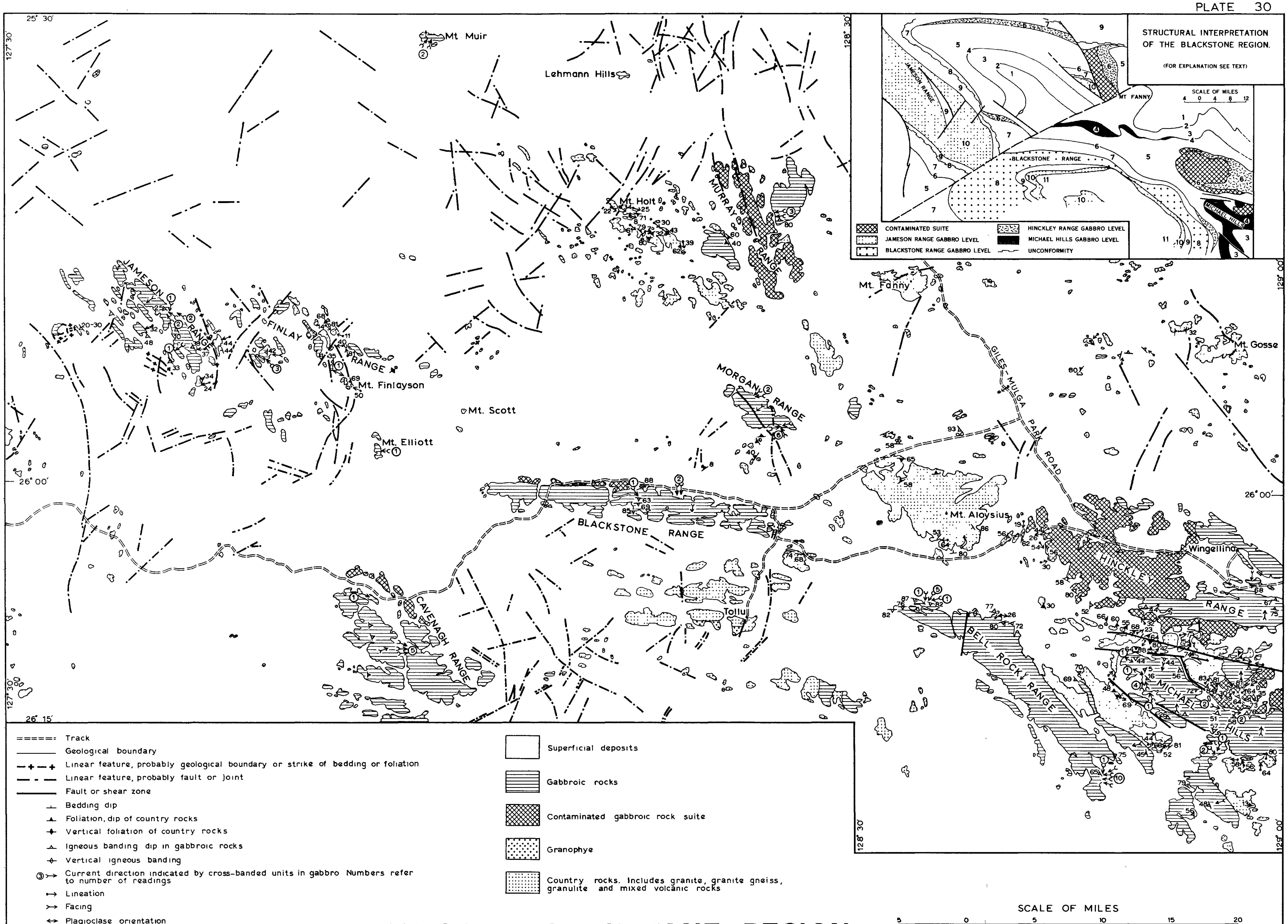
B—Close up of cross-banded unit in gabbro at northwest end of Bell Rock Range ; F 1161.



A—Oriented quartzo-feldspathic blebs in process of assimilation by gabbroic rock, Michael Hills Gabbro ; F 1162.



B—Michael Hills showing benched slopes caused by igneous banding ; F 1163.



GILES COMPLEX – BLACKSTONE REGION

To accompany report by J L Daniels 1966

9580

DIAMOND DRILLING AT THE GERALDINE LEAD MINE, NORTHAMPTON MINERAL FIELD

by L. E. de la Hunty

INTRODUCTION

In the period June 11 to July 4, 1966, a diamond drilling programme was carried out on the abandoned Geraldine lead mine, location 1, Galena. The programme was subsidised, dollar for dollar, by the Government of Western Australia and was supervised by the writer. The drilling was done by a private contractor.

Three holes, 505, 477, and 447 feet long respectively, were drilled at 60 degrees depression. These intersected the ore channel at an average depth of about 370 feet, on the underlay, but did not prove a depth extension of the ore body.

The mine workings are on the western bank of the Murchison River where it flows south, about 3¼ miles west-southwest of the townsite

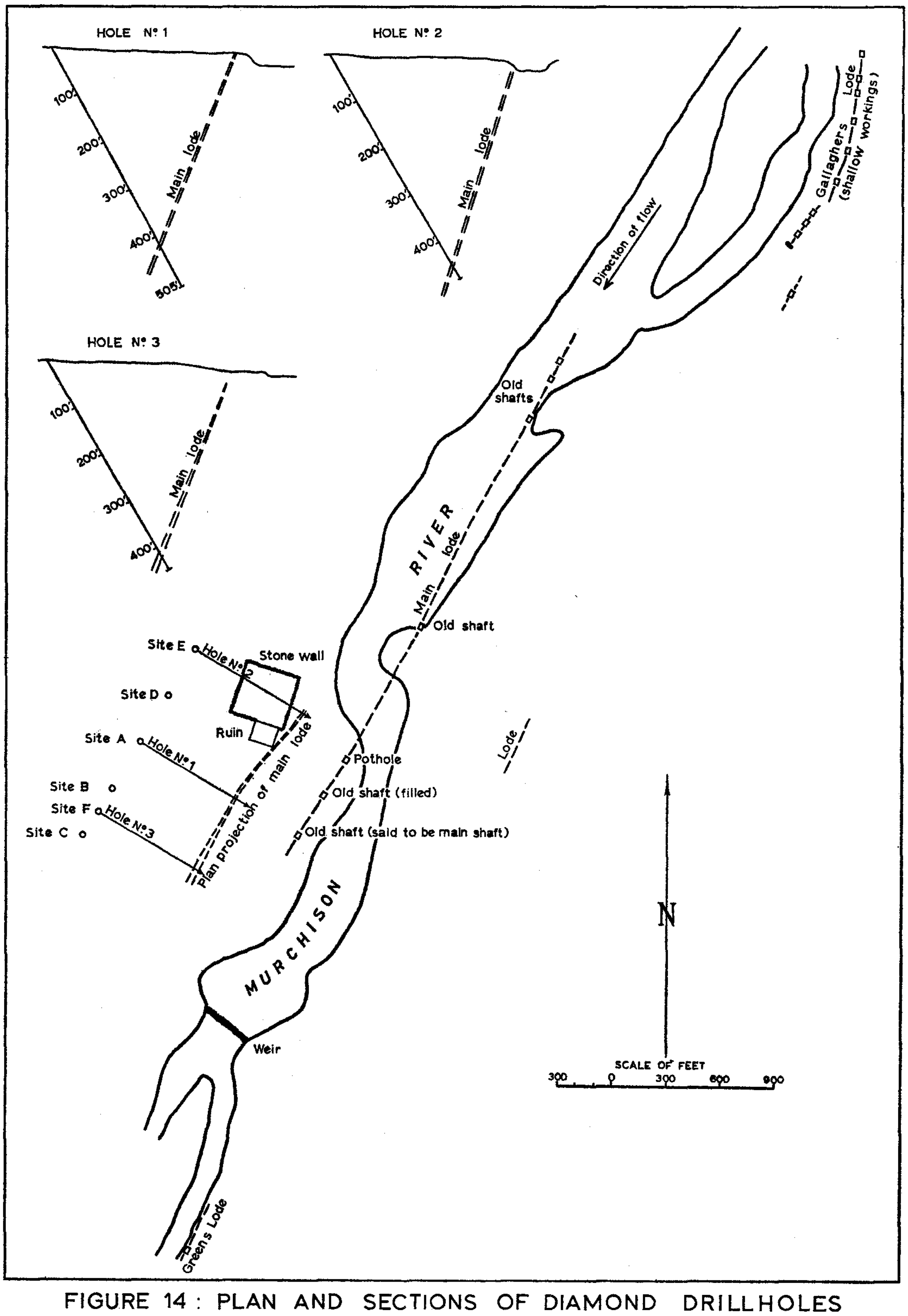


FIGURE 14 : PLAN AND SECTIONS OF DIAMOND DRILLHOLES AT GERALDINE LEAD MINE, NORTHAMPTON MINERAL FIELD

of Galena. Access is by a rough winding track which leaves the North West Coastal Highway a few chains north of the Murchison River bridge.

PRODUCTION

The mine was worked from 1857 to 1878, mostly from 1867 to 1872, and several thousand tons of ore were shipped to London during that time. Although 6,500 tons were recorded, it is believed that much more lead was won. According to local report, an appreciable quantity was mined from Gallaghers Lode (about 500 yards north of the mine) and various people have cleaned up around the old workings over the years.

THE WORKINGS

Wilson's plan (1926, p. 18) shows seven shafts along the main lode ; four in the river bed and three on the western bank. At the time of the present investigation, none of the shafts in the river could be identified but there were dumps on the east bank in the two localities, so Wilson's plot of the shafts has been reproduced on the accompanying figure. However, it seems that the main shaft was the most southerly of those on the west bank, according to elderly residents who were born in the area, and that the hole shown by Wilson as the ' main shaft ' was never more than a pothole.

Woodward reported that the mine was worked from two inclined shafts, the deepest of which was 320 feet (about 290 feet vertical depth), but the distance between the shafts was not recorded. Although there is said to be a drive connecting the main shaft with the shaft 450 feet to the north, there are no plans or sections of the underground workings and it is assumed that the main stope did not extend beneath the bed of the Murchison River.

The only shafts visible now are the main shaft and another, 65 feet north along the main lode, which could have been a ventilation and pumping shaft, since the arrangement of the timbers at the collar indicate that it was not used for hauling ore. The main shaft is collared about 10 feet above the water in the river and is filled with water to river level. The second is filled with broken ore and rock, which also obscures the outcrop of the main lode in the vicinity of the mine.

GEOLOGY

Jones and Noldart (1962) have given a full bibliography of reports on the Northampton Mineral Field and discussed the occurrence of the lead ore bodies. Prider (1958) reported on the area in the vicinity of the Geraldine lead mine.

Except for patches of soil and alluvium, the only rocks within a radius of a mile of the mine are Precambrian garnet granulite, pegmatite, and dolerite. These were described by Prider as :

" . . . fine- to coarse-grained garnet granulites, extensively pegmatised, but otherwise rather uniform and monotonous in character. The granulites have a gneissic structure . . . strike approximately E.-W. and dip from 45° to 65° south. Microcline-rich pegmatites . . . occur throughout the granulites as lenticular masses, elongate parallel to the foliation . . . dolerite dykes . . . in a N.E.-trending swarm."

The granulite, with associated pegmatite is Archaean and the dolerite dykes, which intrude the granulite, are late Proterozoic or early Palaeozoic in age.

Prider described a specimen of garnet granulite from the dump of the Geraldine mine as :

" . . . even, fine- to medium-grained, and consist of a granulose aggregate of pale pink garnet, white microcline and grey quartz with accessory biotite and flake graphite. . . . Under the microscope the texture is even-granoblastic, with a slight gneissic structure due to sub-parallel orientation of the biotite and graphite flakes and elongate quartz grains. The minerals in order of abundance are quartz, microcline, oligoclase-albite, garnet, biotite and graphite, with zircon and monazite as minor accessories. . . . The garnet is . . . dispersed uniformly throughout the rock, in grains to 1·7 mm diameter. It is an almandine."

Almost complete replacement of garnet by chlorite was noticed in some outcrops and chlorite is well-developed in the vicinity of the ore channel. There was abundant chlorite in the drill core. The biotite in the core was bronze-coloured and probably iron-rich.

Jones and Noldart (1962, p. 39) wrote :

" The lead and copper deposits are confined to the N.E. tension fractures near or alongside the dolerite dykes. The host rocks are garnet granulite, quartzite and rarely dolerite, although there are numerous small ore bodies along the dolerite-granulite contacts.

Siliceous brecciated gangue and numerous vugs up to 2-3 feet diameter are characteristic of the ore. The main sulphide minerals are galena, sphalerite, pyrite, marcasite and chalcopyrite. Octahedral galena, of 5 cm maximum size, and quartz crystals are usual in the vug linings of the lead ore. Sphalerite is not intimately mixed with the galena. . . . Barite is common in the gangue . . . it forms most of the vein . . . in the Surprise Mine at Galena."

The main lode at the Geraldine lead mine is in a shear zone in garnet granulite and it is parallel with the trend of nearby dolerite dykes. The nearest dolerite dykes are 300 yards to the southeast and 600 yards to the northwest.

Specimens from the mine dump indicated that the ore body was composed of sheared and brecciated, chloritized garnet granulite ; with many vugs containing galena, brown sphalerite, and minor pyrite and chalcopyrite, together with abundant small crystals of quartz. This was confirmed by the drilling which also revealed a tendency for the concentration of galena at the hanging wall of the lode and sphalerite at the footwall. The lode is weathered and cavernous ; drilling water was lost and core recovery was poor near the hanging wall in Hole 3.

DRILLING RESULTS

Hole 1 intersected the mineralized zone at an underlay depth of 380 feet below the collar of the main shaft but the sulphide zones were disappointingly narrow. Holes 2 and 3 were drilled to test the lode on either side of No. 1, and these indicated that the ore shoot did not extend in depth either vertically, or with a low plunge north or south.

The main lode was found to steepen slightly at Hole 2 but the strike and dip of the lode was found reasonably constant in depth, as well as in outcrop.

As can be seen from the tabulated comparison of drilling results below, the intersections made in Holes 2 and 3 were poorer than those in Hole 1, and the mineralized zones were wider than in Hole 1. With the exception of a little galena in Hole 2 and a ½-inch seam of sphalerite in Hole 3, all galena and sphalerite intersections were confined to the main mineralized zone. The galena was restricted to the hanging wall and the sphalerite to the footwall. Both the galena and the sphalerite intersections were better in Hole 1 and, although only 2 inches of galena was cored at the hanging wall, it is possible that the seam was 5 inches wide, corresponding to a true thickness of about 4 inches.

The cavity at 412 feet in Hole 3 is at the hanging wall (galena zone) of the lode and the possibility that the drill encountered an old stope must be considered. There is no possibility that the drillhole lifted, since the acid-tube dip surveys indicated a reasonably consistent dip to all three drillholes, and the positions of the sulphide intersections in the hole support the survey results.

COMPARISON OF DRILLING RESULTS

	Hole 1	Hole 2	Hole 3
Length	505 feet	477 feet	447 feet
Cavities, with loss of drilling water	1′ at 137′; 1′ at 240′	None	3′ at 412′
Core recovery in mineralized zone	High	High	Low
Intersections outside main mineralized zone	None	½ in. core at 403′ contains a little galena	⅛ in. seam of sphalerite at 401′
Hanging wall of shear zone	415′	440′	404′
Hanging wall of mineralized zone	417′	446′	409′
Footwall of mineralized shear zone	421′	454′	421′
Width of mineralized zone	4′	8′	12′
Total width of galena intersections	2½ (4½?) ins.	¼ in.	12 ins.
Proportion of galena in intersections	High	High	Very low
Total width of sphalerite intersections	6¾ ins.	4⅛ ins.	1¾ ins.
Proportion of sphalerite in intersections	High	30%	High
Total width of sulphide intersections	9¼ (11¼?) ins.	4⅜ ins.	13¾ ins.
Proportion of sulphides in intersections	High	Medium	Low

It could be contended that the old workings were deeper than the recorded 320 feet, and there is no concrete evidence against such a suggestion. However, Jones and Noldart noted that 2 to 3 feet diameter vugs are 'characteristic' of the ore bodies in the area. Furthermore the presence of soft, weathered granulite at 404 to to 406 feet in the core, also towards the footwall, supports the contention that the cavity is a natural one which has been accessible to circulating groundwater for a very long time.

CONCLUSIONS

1. The drilling programme has indicated that the ore body of the Geraldine lead mine does not extend 370 feet, on the underlay, beneath the outcrop.

2. The possibility that the ore body might have a low angle of plunge was adequately tested.

3. The galena was concentrated at the hanging wall of the mineralized zone and the sphalerite at the foot wall.

4. Future exploration for lead in this vicinity could be directed towards Gallaghers Lode, 500 yards upstream on the eastern bank, and also to Greens Lode, about 300 yards downstream on the eastern bank. Gallagher's workings are only shallow, and a pit on Greens Lode has exposed a 6-inch seam of galena beneath 3 feet of colluvium.

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COPPER DEPOSITS OF THE LITTLE TARRAJI RIVER AND OTHER AREAS OF THE YAMPI 1:250,000 SHEET AREA, WEST KIMBERLEY

by John Sofoulis

ABSTRACT

Minor copper mineralization is widespread in the Precambrian rocks of the Yampi 1:250,000 Sheet (SE/51-3) area. The significant deposits are associated with veins and reefs of quartz and with silicified, sericitic shear and fault zones. These occurrences are mostly restricted to a belt of Halls Creek Metamorphics that extends south and southeast from the Little Tarraji River area. Small showings of copper along the southeast extension of this same belt have been prospected at Mondooma and at Limestone Spring. Similar metamorphic rocks of the Townsend River—Mount Nellie area, north of Oobagooma, contain copper mineralization but not in economic amounts.

The only copper ore mined from the younger Precambrian Kimberley Group has been at the head of Coppermine Creek near Yampi Sound. This deposit is associated with quartz veins impregnating a sericitized and carbonated quartz porphyry which intrudes the Kimberley Group. There are minor occurrences of disseminated chalcopyrite in both the Carson Volcanics of the Kimberley Group and the younger intrusive Hart Dolerite.

COPPER PRODUCTION

Table 1 shows the total copper production recorded from the Yampi 1:250,000 Sheet area. This ore was mined during the period 1905 to 1920, when 109·52 tons of copper ore containing 25·92 tons of metallic copper, valued at \$A3,418 was produced. Copper ore produced prior to 1914 and not reported to the Mines Department would probably amount to less than 350 tons.

A locality plan of the known copper occurrences of the Sheet area is shown on Plate 31A.

Table 1
REPORTED COPPER PRODUCTION—YAMPI 1:250,000 SHEET AREA

Centre	Lease	Name	Period	Quantity Tons	Metallic Content Tons	Value $A
Monarch Group	ML227H	Holbrook	1915	4·22	0·94	128·00
	ML228H	Abagama	1915	8·97	1·82	272·00
Coppermine Creek	ML221H	Yampi Sound Copper Mine	1914	38·50	9·21	852·00
	ML221H		1915	54·36	13·59	2,094·00
	Sundry Persons		1916	3·47	0·36	72·00
			Total	109·52	25·92	3,418·00

GEOLOGICAL INVESTIGATIONS

The geological information given on the various copper deposits of the area by Maitland (1919) and Simpson (1952) is summarized by Low (1963). The same deposits are described also by Harms (1959). An extensive study of the copper mineralization in the area was made by Western Mining Corporation Ltd., during their tenure of Temporary Reserve 1593H (December 1957—October 1960). This company conducted a series of reconnaissance and detailed geological, geochemical and geophysical surveys over the metamorphic rocks and adjacent terrains, and subsequently drilled prospects at Grants Find and Wilsons Reward.

The various phases of this exploration programme are described in unpublished company reports by Woodall (1957), Triglavcanin (1958), Harper (1959), and Reid (1958, 1959).

The area is now included in Temporary Reserve 2680H held by Pickands Mather & Co. International, who are currently engaged in a programme of regional mapping and geochemical sampling.

The significant copper occurrences of the area are described in this report. Most of these were inspected by the writer or by other members of the geological party during a regional mapping project conducted jointly by the Bureau of Mineral Resources and the Geological Survey of Western Australia in the area during 1966.

Permission to quote information from unpublished company reports was kindly granted by Mr. J. D. Campbell, Chief Geologist of Western Mining Corporation Ltd.

LITTLE TARRAJI RIVER DEPOSITS

Copper mineralization was first reported from the Little Tarraji River area in 1905, the general locality then being referred to as ' east of Mount Nellie.' Abandoned groups of copper workings in this area are shown now on the Yampi 1:250,000 military sheet area as Grants Find, Tarraji, and Monarch Group. Further workings north of the Monarch Group are known also as Wilsons Reward or Berylton.

Plate 31B is a locality plan of the groups of copper workings and reported centres of copper mineralization.

LOCATION AND ACCESS

The copper deposits are north of the Tarraji River on the Oobagooma pastoral property. Oobagooma homestead, the nearest permanent settlement, is about 20 miles southwest of the deposits. A graded road connects Oobagooma to the port of Derby approximately 100 miles distant.

Access to the easternmost copper localities may be gained from a graded road which extends north from Kimberley Downs homestead through Limestone Spring to Mondooma on the Robinson River. Alternative cross country access to the various copper localities may be gained by four-wheel drive vehicle from either Oobagooma or Mondooma.

GENERAL GEOLOGY

The copper mineralization of the Little Tarraji River area is associated with veins and reefs of quartz which occupy faults or impregnate sericitized shear zones in a metamorphic sequence of steeply dipping sericite-chlorite-muscovite schists, slates, meta-arenites, and amphibolites of the Halls Creek Group. These rocks are intruded, and flanked to the east and west by granite of the Lamboo Complex. In the northern part of the area both the metamorphic rocks and granite are overlain unconformably by younger Precambrian rocks of the Kimberley Group, which are intruded by sills and dykes of the Hart Dolerite at several stratigraphic levels.

GEOCHEMICAL SURVEY

Copper

Soils of the area were systematically sampled by Western Mining Corporation during the 1958 field season. The samples were tested for copper by cold extraction field techniques and gave results which ranged from 1 ppm to 40 ppm of copper (Reid, 1958). Results greater than 2 ppm (taken as background value) were regarded as anomalous. The survey showed that the main anomalies correspond to areas of copper mineralization known within the Halls Creek Metamorphics. Other high values were attributed to the higher copper content in amphibolite of the Halls Creek Group and in the younger Hart Dolerite intrusives, but in these instances the results were not regarded as significant.

Further soil samples collected from the same area during the 1959 field season were tested for copper by total extraction methods using bisulphate fusion with estimation by cuproine. Background values ranged from 10 ppm or less of copper on granitic soils, to 50 ppm or more on shallow soils overlying Halls Creek Metamorphics. High values up to 200 ppm of copper were recorded from amphibolites effectively masking any mineralization associated with these rocks. Values above 100 ppm of copper were regarded as anomalous. The only significant anomalies outlined in the survey corresponded to the known areas of copper mineralization at Grants Find and Wilsons Reward. Other high values were associated with amphibolite or resulted from minor copper showings on faults or shear zones within the metamorphics. A total of 3,677 samples were tested in the complete programme.

Zinc

Of the 611 samples collected during the 1958 copper survey, 147 of them were tested for zinc by total extraction techniques. Results obtained ranged from 1 ppm to 12 ppm of zinc, but no concentration of high values could be demonstrated as the results were not regarded as anomalous for the technique used (Reid, 1958).

MAGNETIC SURVEY

A reconnaissance magnetic survey of the Little Tarraji River area (Triglavcanin, 1958) showed that the highest values of magnetic intensity corresponded to amphibolites and this helped to distinguish amphilobites from metasediments. Boundaries between metasediments and granite also were traced despite very small differences in magnetic intensity. However the detection or indication of copper mineralization was not possible as the differences in magnetic intensity between mineralized and non-mineralized rocks were considered too small to be diagnostic.

SELF POTENTIAL SURVEY

Self potential surveys were conducted by Western Mining Corporation Ltd. over a large part of the area (Triglavcanin, 1958, Harper, 1959). Anomalies were recorded over all the known occurrences of copper but only those at Grants Find and Wilsons Reward could be ascribed to worthwhile mineralization.

In neither locality did the self potential survey reveal extensions of the deposits beneath adjacent alluvium, nor did it indicate deposits of economic potential below soil cover in any other part of the Little Tarraji River valley.

GRANTS FIND WORKINGS

The abandoned copper workings at Grants Find are known also as Grants Prospect, Grants Reward, or Mount Nellie Deposit.

Copper mineralization at this locality can be traced in a fairly continuous line for more than half a mile. The more significant showings of copper are confined to a prominent quartz reef which rises 75 feet above the surrounding plain level. The quartz reef strikes 40° to 45° east of north and dips southeast at 70° to 85°. It consists of multiple pinch and swell quartz layers and contains thin discontinuous lenses and bands of schist, forming a composite banded reef 2 to 6 feet wide.

Disseminated malachite and minor cuprite are associated with limonite and confined mainly to the eastern or hanging wall side of the reef. However, this mineralization is not continuous and large sections of the reef appear barren. Schist remnants within the reef commonly have a higher copper content, and there are malachite stains and thin coatings along joints and partings in the oxidized schist adjacent to the mineralized sections of the hanging wall.

Plate 31C is a plan of the Grants Find reef and workings. The reef has been worked from a vertical shaft sunk on a richer shoot of ore. The shaft was sunk 35 feet at the hanging wall contact with slates, this depth being the lower limit of oxidation. Unstoped hanging wall drives at this depth extend 160 feet and two adits (one of which has now collapsed) provided access to the drives from the western side of the ridge.

Harms (1959) noted that the ore body consists of quartz with disseminated copper minerals and is 2 foot 6 inches wide at the bottom of the shaft and 5 feet wide at the junction of the north adit and drive. Some ore left in the ore paddock adjoining the shaft consists mainly of limonite-stained quartz with disseminated malachite, and minor cuprite and malachite in joints and partings.

A small parcel of copper ore was open cut from the south extension of the reef. Ore broken at this locality was allowed to fall to the scree floor adjoining the hanging wall. A parallel reef 25 feet west of this locality contained only minor copper disseminations.

Grants South workings

A discontinuous quartz reef, which is probably a dislocated strike extension of the Grants Find reef, crops out as a prominent ridge ¾ of a mile southwest of Grants Find shaft. The reef is generally 18 inches to 2 feet wide but there are local zones of mineralization up to 5 feet wide. These consist of schist impregnated by numerous malachite-stained quartz stringers. Some of the quartz veins contain lenticular bunches of disseminated malachite as well as thin malachite veinlets up to several inches thick. The copper showings are commonly associated with iron oxides.

A small parcel of ore has been mined from a pit now 8 feet deep on the eastern slope of the southern end of the ridge approximately 50 feet above plain level. Other quartz veins and reefs in this ridge are barren or have only minor copper showings.

Diamond drilling

The geophysical anomaly outlined at Grants Find was described by Harper (1959) as being broad, closed on three sides, and having negative values of -60 mv (millivolts) extending over 300 feet and -100 mv over 200 feet. Six diamond drillholes, of total footage 3,111 feet, were drilled to test the prospect ; five into the main northern part of the Grants Find reef and one into the probable south extension of the same line of mineralization. The holes were planned to intersect the reef 300 to 400 feet below the outcrop.

The main rock types encountered in the drillholes were quartzite, slate, amphibolite, and feldspar porphyry. Unoxidized rocks were intersected 30 to 50 feet below the surface. Reid (1959) noted that the amphibolite was usually carbonated, and the porphyry occasionally so, and that the porphyry contained small blebs of chalcopyrite. In several holes the slate was silicified at the porphyry contact.

The drilling results are summarized in Table 2.

Table 2

DRILLING RESULTS—GRANTS FIND*

Hole	Length of Intersection	Assay % Cu	Remarks
GS1	17 feet 6 inches True width 12 feet	1·14	Highest 27 inches at 2·95% Cu. H.W. vein 17 inches at 5·34% Cu.
GS2	28 feet True width 19 feet	1·23	Contains zone 9 feet 6 inches at 3·25% Cu.
GS3	4 feet 10 inches 5 feet 1 inch	1·3 2·6	Separated by 20 feet of barren rock.
GS4	Main lode almost barren, not assayed	....	H.W. vein 60 inches at 0·63% Cu.
GS5	13 feet 6 inches True width 10 feet	1·29	Included 7 feet at 2·22% Cu.
GS6	No mineralization	....	

* Drilled by Western Mining Corporation Ltd. Data from Reid (1959).

The drilling indicated that the pitch of the ore shoots was about vertical and that the grade of the lode intersections in all cases resembled that of the surface outcrop vertically above. The mineralization was primarily chalcopyrite in quartz, and better grade intersections of the Grants Find reef averaged 1·5% to 2% copper over an average width of 10 feet. Reid (1959) estimated that 11,000 tons per vertical foot of ore at this grade would persist to a depth of at least 400 feet.

TARRAJI OR MT. NELLIE SOUTH WORKINGS (Harms, 1959)

A quartz reef about 1½ miles south of Grants Find shaft is probably a dislocated strike extension of the Grants Find reef. Here the quartz reef is a foot wide and has copper mineralization, where it is exposed in a shallow trench, over a length of 15 feet. This reef is nearly vertical and strikes 320° parallel to the enclosing schists. A shaft sunk 25 feet deep on the line of reef, approximately 1 chain south of the trench, failed to intersect a defined lode.

WILSONS REWARD WORKINGS

This locality is also known as Berylton or Wilsons Prospect. The workings are on the flanks of a low ridge approximately 5½ miles southeast of Grants Find.

The copper mineralization is associated with quartz reefs and veins which trend 20° to 30° west of north and intrude folded phyllitic and amphibolitic schists. Individual lodes are usually a few inches wide and up to 10 feet long, and carry only disseminated malachite. A shaft about 50 feet deep and several shallow trenches and pits failed to locate an economic deposit.

Diamond drilling

The geophysical anomaly outlined at Wilsons Reward was not as well defined as that of Grants Find. Negative values exceeded -40 mv at only a few points close to the outcrop (Harper, 1959). Four diamond drillholes, of total footage 2,478 feet, were drilled to intersect the lode 300-400 feet below the surface. Plate 31D is a plan of the drillholes.

Oxidation is relatively shallow and fresh rocks are encountered 50 to 70 feet below the surface. The main rock types intersected were quartzite, phyllite, and amphibolite ; the amphibolite was usually carbonated. Lode intersections were made in all four holes. These consisted of phyllite, partly replaced by quartz with pyrite, subordinate amounts of chalcopyrite, and occasional pyrrhotite. There were small blebs of pyrrhotite on shear planes throughout much of the country rock and some pyrite along joints. The drilling results are summarized in Table 3.

Table 3

DRILLING RESULTS—WILSONS REWARD*

Hole Length of Intersection		Assay % Cu	Remarks
WS1	33 feet	Less than 0·1	Contained 24 inches at 1.35% Cu.
WS2	42 feet 7 inches....	Less than 0·25	Highest 14 inches at 0.4% Cu.
WS3	12 feet 5 inches	1·4	17% Core recovery.
WS4	35 feet	0·83 inc. 21" at 4·1	Drilled to cover possible vertical dip of lode.

* Drilled by Western Mining Corporation Ltd. Data from Reid (1959).

In all holes except WS3, amphibolite was the principal footwall rock. In WS3 the footwall rock was primarily quartzitic and resembled the hanging wall of the lode. This suggested that only the nose of the fold was intersected and that the folded lode either pitched south rather than southeast, as was inferred from the surface mapping, or else the hole had deflected to the east.

Reid (1959) considered that the chances of locating a sizeable tonnage of high grade ore at Wilsons Reward were remote, although the drilling test could not be regarded as complete.

MONARCH GROUP

The area south of Wilsons Reward contains scattered shallow workings which are collectively known as the Monarch Group or Monarch

Workings. Schists of this locality are intruded locally by quartz reefs and veinlets with disseminated copper mineralization. Sharp anomalies of limited extent were recorded in the area during the self potential survey made by Western Mining Corporation Ltd. (Harper, 1959). Some single readings greater than -100 mv were attributed to small pods of copper minerals in veins of quartz.

Some small parcels of copper ore may have been recovered from the area but the copper showings are generally too small to be of economic importance.

ASSAYS FROM LITTLE TARRAJI RIVER COPPER ORES

Simpson (1952) assayed seventeen bulk samples of copper ore from the Little Tarraji River workings. They were collected in 1911 by agents of a German syndicate which was then working several leases in the area. The samples assayed from 2·20% to 16·04% Cu with an average of 7·37% Cu. The chief copper mineral of all the samples collected was malachite. An analysis of the combined sample gave :

	Per Cent
CuO	9·23
Zn, Bi, Sb	nil
Pb, Ni, Mn	trace
As	0·04
Fe_2O_3	8·21
Al_2O_3	5·86
CaO	nil
MgO	0·83
SiO_2	68·83
CO_2	2·56
S	0·08
O, H_2O, and loss	4·36
	100·00

Selected samples of carbonate ore from this area assayed as follows :

Copper %	Lead %	Gold ton	Silver ton		Remarks
		grns	dwts	grns	*Grants Find ore* : cellular mixtures of malachite and limonite with a little quartz.
34·63	0·72	20	4	22	
23·22	nil	20	1	15	
37·58	nil	20	11	10	*Wilsons Reward ore* : massive liver ore with patches of quartz and malachite.

OTHER COPPER OCCURRENCES

ROUGH TRIANGLE PROSPECT

A prospect consisting of a silicified and ferruginized sericitic schist zone was located by Western Mining Corporation Ltd. in hilly schist country approximately 2½ miles west of Grants Find. The line of mineralization which trends north and dips steeply east, can be traced almost continuously for 60 chains. The average width of the zone is 4 feet and the greatest width is 15 feet. There is minor copper mineralization along the zone with richer occurrences where quartz is less abundant (Reid, 1958).

A small parallel lode with similar mineralization is exposed on the banks of a small creek 250 feet east of the main line. Float from this line can be traced for about 1,000 feet south. Despite their length, neither line of mineralization contains economic ore bodies.

AMPHIBOLITE PROSPECT

Sporadic copper mineralization, associated with iron oxides, is exposed along a shear zone in the younger Precambrian Hart Dolerite north of Rough Triangle prospect. The shear zone is intensely sericitized and contains patchy silicification and minor quartz veins.

The mineralized shear zone is part of a strong fault which can be traced on air photos for several miles to the north and dies out to the south in the Rough Triangle area. The line of mineralization has been prospected by three shallow pits sunk in a gossanous ore consisting of a mixture of malachite, bornite, cuprite, and iron oxides.

TOWNSEND RIVER—MOUNT NELLIE AREA

Several small copper showings are associated with quartz in sericitic shear zones of the Halls Creek Metamorphics north of Oobagooma. The principal showings are referred to as Mangrove Prospect and Townsend River A, B, and C Prospects (Reid, 1958; Simpson, 1952). None of the deposits are economic.

Other showings in this locality are very small and are of little significance. However, they indicate the regional extent of copper mineralization in this area.

MONDOOMA

Some copper workings located 3 miles northwesterly from Mondooma Yard were described by Harms (1959) as the Mondooma Copper Show. Simpson (1952) and Low (1963) referred to the same workings as the Robinson River copper mine.

The workings are in a belt of Halls Creek Metamorphics which extend southeasterly from the Little Tarraji River deposits. The Mondooma workings are north of the Robinson River, in a prominent northwest trending ridge that rises 150 feet above plain level. Granite of the Lamboo Complex flanks the ridge to the northeast.

A prominent quartz reef, subparallel to the schistosity of the metamorphics, can be traced for about 420 yards along the crest of the ridge. Copper staining is visible over half this length.

Harms (1959) noted that the reef, where copper stained, ranges from 3 to 15 feet in width but is barren over most of this width. Primary copper mineralization is apparently confined to soft, iron-stained and kaolinized lenses up to 2 feet wide, from which secondary carbonates have been derived.

Some richer portions of the ore were investigated by trench and a shaft sunk to 10 feet but these did not indicate mineralization of economic grade. Reconnaissance by Western Mining Corporation Ltd. failed to reveal any significant copper mineralization other than that already known, although a large number of quartz veins with occasional rich showings of iron oxides occur throughout the belt (Reid, 1958). A similar quartz vein 4 miles southeast of Mondooma parallels the Mondooma reef but no mineralization is evident.

LIMESTONE SPRING

There are shallow workings 2 miles north of Limestone Spring in a belt of low rises consisting of sericite schist and amphibolite. These rocks trend northwest and are a further southeasterly extension of the Halls Creek Metamorphics from Mondooma. A ferruginized quartz reef, stained with copper carbonates and traces of chalcocite, constitutes the line of mineralization which can be traced for a distance of 300 yards. This reef has been prospected from an inclined shaft about 20 feet deep, a shallow trench 25 feet long, and from a costean.

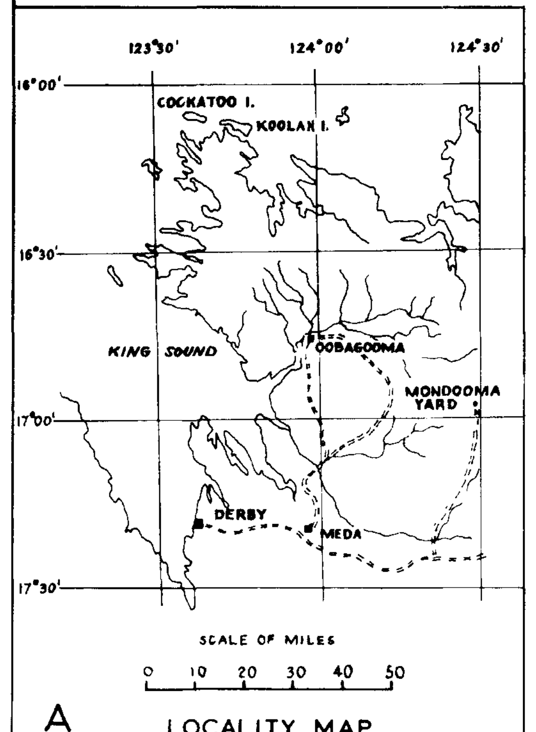
There is no official record of production from this area and from the paucity of mineralization the prospect does not appear to warrant further work.

COPPER MINE CREEK DEPOSIT

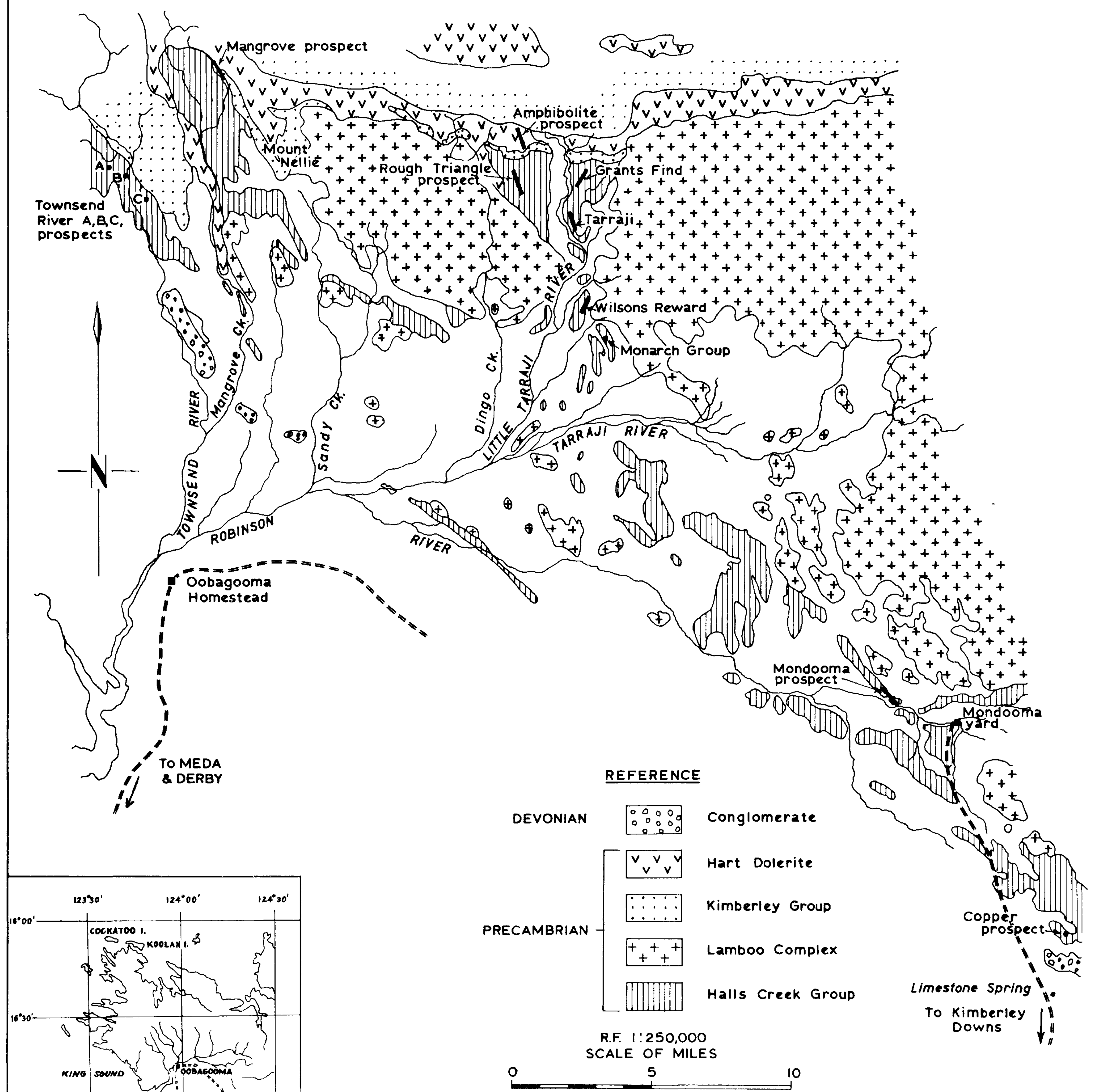
The only copper ore mined from the younger Precambrian (Kimberley Group) has been that from the Yampi Sound copper mine. This mine is on the mainland coast at the head of Coppermine Creek approximately 10 miles south of Cockatoo Island. Low (1963) referred to this deposit as Yampi Sound copper deposit, Water Point.

The mineralization is localized in a probable fault zone and consists of copper minerals associated with quartz veins which impregnate sheared, sericitized and carbonated quartz porphyry. Maitland (1919) recorded that the width of the lode at this deposit ranges between 5 and 6 feet and that it underlies to the east. Ore mined from this deposit was described by Simpson (1952) as containing masses of chalcocite, associated with malachite, cuprite, atacamite (copper oxychloride), and brochantite (basic copper sulphate). The deposit has not been worked since 1915. Reported production for the years 1912–1915 was 92·86 tons of copper ore containing 22·70 tons of copper valued at $A2,946.

It is probable that the porphyry contains further mineralized zones. From the 1966 map-



A LOCALITY MAP



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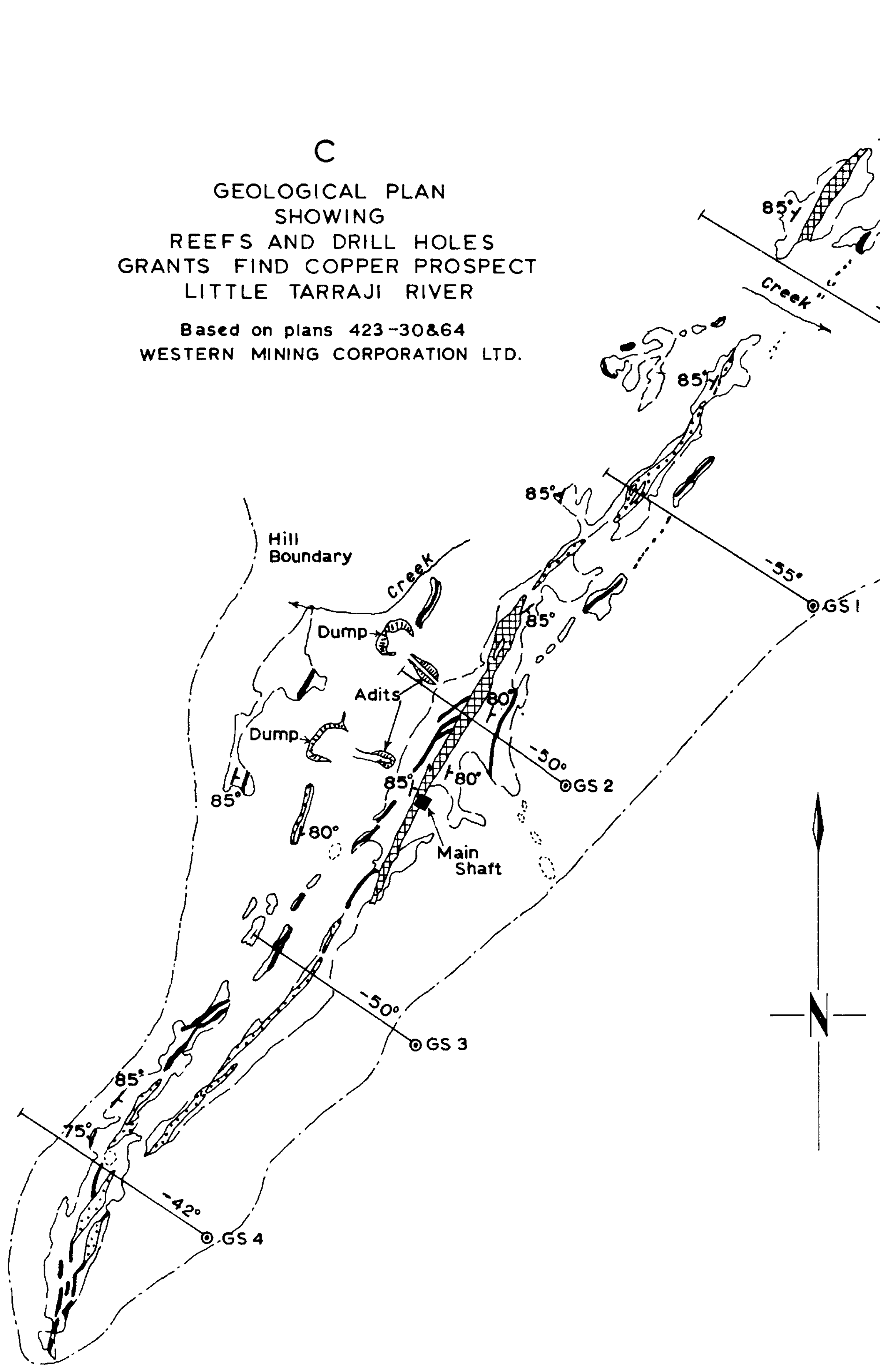
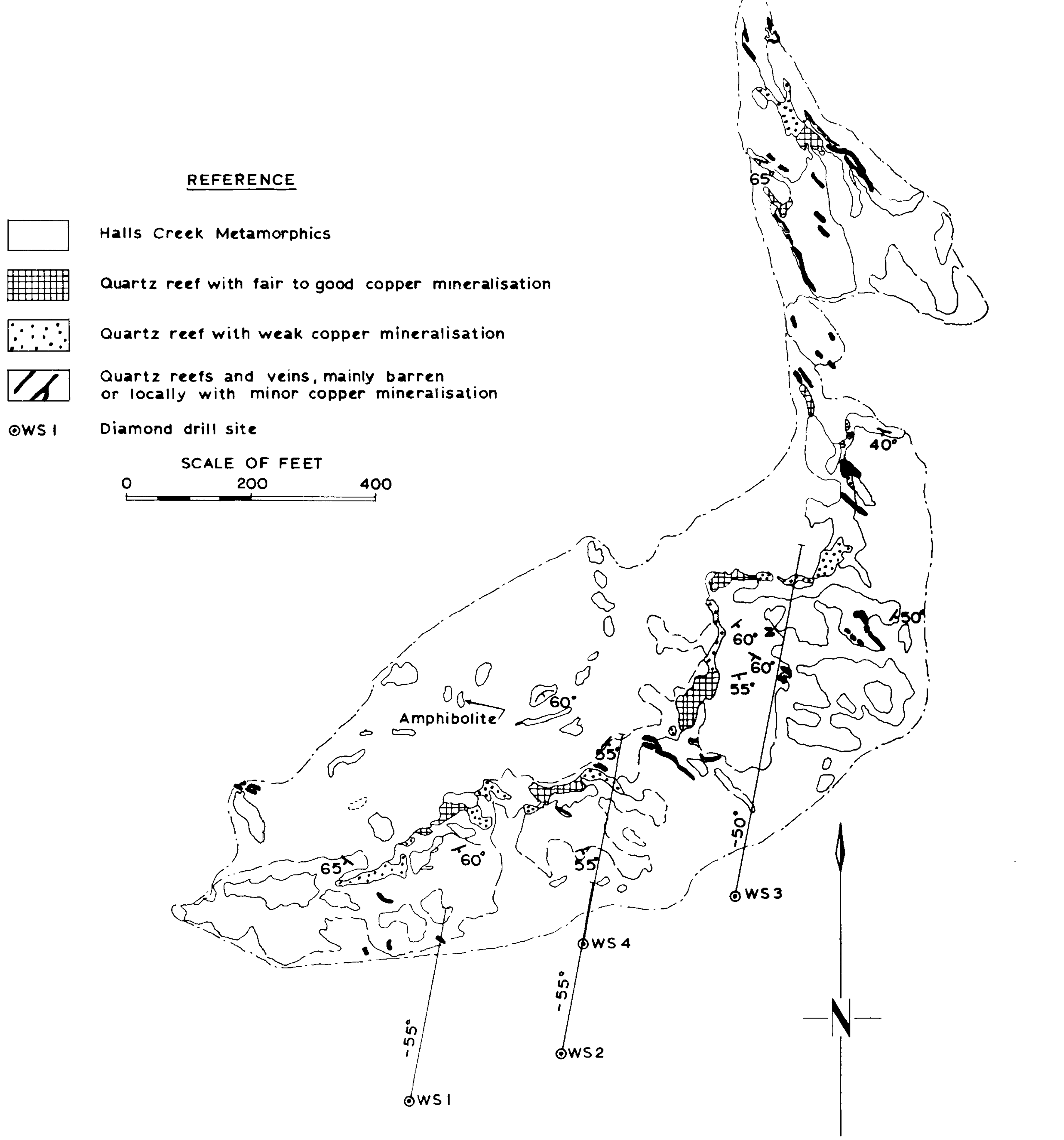
GEOLOGICAL SKETCH MAP
OF
LITTLE TARRAJI RIVER
AND
OTHER COPPER LOCALITIES

C

GEOLOGICAL PLAN
SHOWING
REEFS AND DRILL HOLES
GRANTS FIND COPPER PROSPECT
LITTLE TARRAJI RIVER

Based on plans 423-30&64
WESTERN MINING CORPORATION LTD.





D

GEOLOGICAL PLAN
SHOWING
REEFS AND DRILL HOLES
WILSONS REWARD COPPER PROSPECT
LITTLE TARRAJI RIVER

Based on plan 423-65
WESTERN MINING CORPORATION LTD.

9652

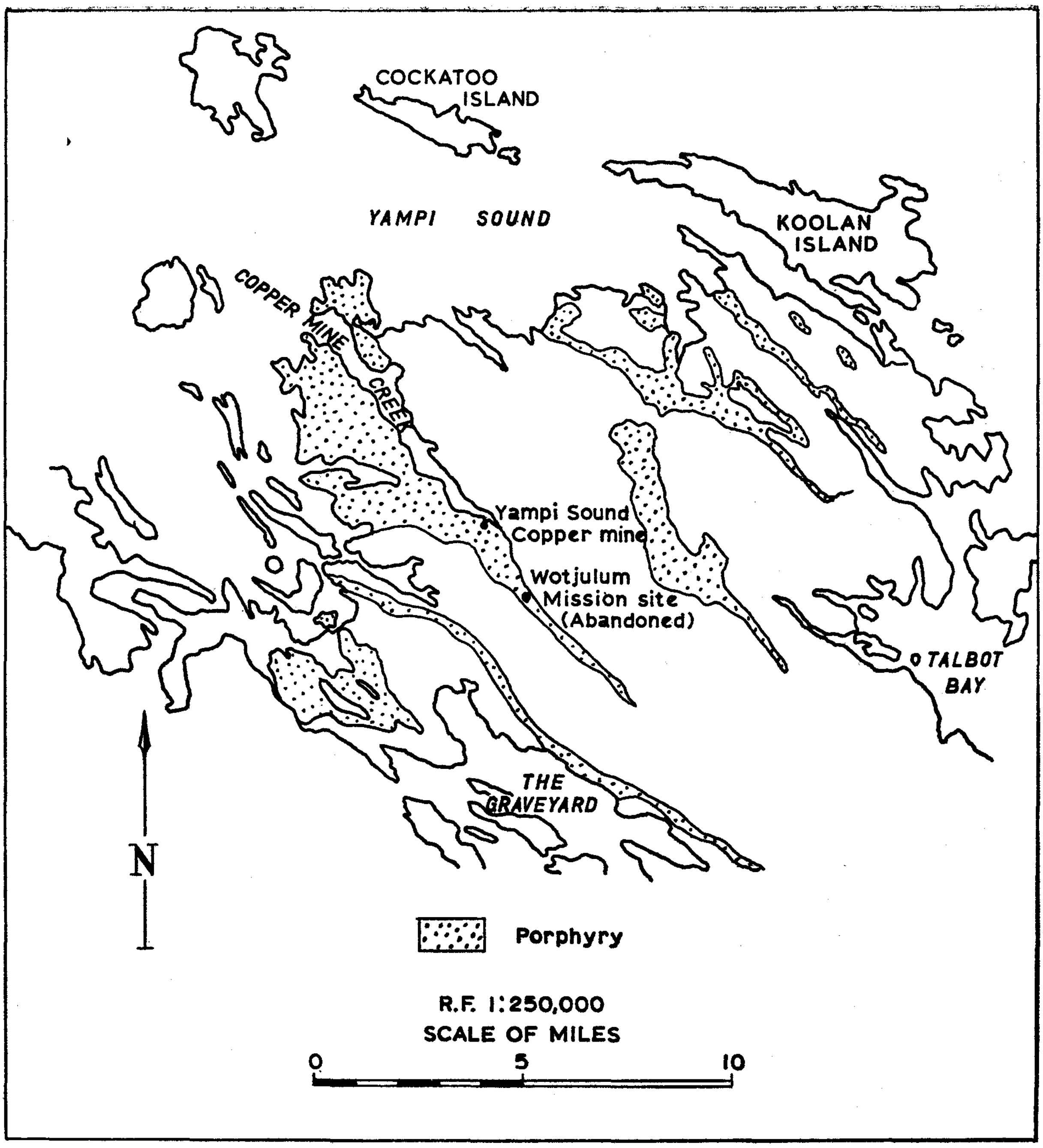


FIGURE 15: LOCALITY AND GEOLOGICAL SKETCH MAP OF PORPHYRY DISTRIBUTION, NORTHWEST YAMPI PENINSULA

ping, it is known that the porphyry intrudes the Elgee Siltstone horizon of the Kimberley Group. The same porphyry is repeated in the area by folding, and has an extensive distribution in the northwestern part of the Yampi Peninsula.

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MICA DEPOSITS OF THE WEST KIMBERLEY AREA, WESTERN AUSTRALIA

by John Sofoulis

INTRODUCTION

Mica production in Western Australia and other Australian States virtually ceased with the termination of the mica mining subsidy by the Commonwealth Mica Pool. All requirements of sheet and block mica are now imported from India while ground and pulverised mica is obtained mainly from South Africa and the United Kingdom.

Two pegmatite dykes, previously mined for sheet muscovite, are located on the Napier Downs and Kimberley Downs properties in the West Kimberley. The mica shows are referred to respectively as Gussys mica deposit and Stuarts mica mine. Each is approximately 100 miles by road inland from the port of Derby.

The deposits, abandoned at present, were inspected in 1966 during the course of a regional mapping programme conducted jointly by the Bureau of Mineral Resources and the Geological Survey of Western Australia. Locality maps and geological plans of the workings are shown on the accompanying plate.

Both deposits could yield small quantities of high grade muscovite.

GUSSYS MICA DEPOSIT

Gussys mica deposit is approximately 6 miles northeast of Napier Downs homestead and 1½ miles southeast of Kongorow Pool on the Barker River. The deposit is known also as Kongarrah or Barker Gorge mica mine. It was last worked for mica as P.A.s 47 and 49 during 1943-44 but the production was not reported. The earlier excavations were examined by Finucane and Jones (1939). Other reports on the same occurrence are given by Simpson (1952) and Harms (1959).

General geology

The pegmatite occurs in soil covered country as scattered, low, discontinuous outcrops aligned northwesterly. It intrudes a sequence of chlorite-biotite schists, amphibolites, and meta-arenites of the Halls Creek Group and lies close to the contact of the Halls Creek Group with a coarse-grained, porphyritic feldspar-biotite granite of the Lamboo Complex (see Plate 32).

Both the pegmatite dyke and metamorphic rocks strike northwest and dip southwest at 55° to 75°. Foliations recorded in the adjacent granite have similar attitudes as well as a pronounced lineation plunging southeasterly at 40° to 50°. Dolerite dykes, trending west-northwest, and a network of tourmaline pegmatite and aplite veinlets also intrude the granite near the deposit.

Pegmatite workings

The pegmatite has been tested over a length of about 900 feet by a series of shallow prospecting pits, shafts, and costeans. The deepest shaft is said to have been 30 feet deep but most of the excavations are wash-filled through cyclonic rains and few are now deeper than 4 feet.

Available exposures suggest that the pegmatite consists of an irregular quartz core, flanked by outer zones of quartz, muscovite, and microcline feldspar. Accessory minerals include black tourmaline (usually associated with quartz), sericite, and occasional garnet. A few small crystals and pieces of beryl were recovered from a dump in the central part of the area. Lithium minerals were not recorded.

Pinch and swell structures give the pegmatite a width ranging from 4 to 15 feet. Good quality muscovite is restricted to the outer zone of the pegmatite, and mica books are usually oriented normal to the pegmatite walls in zones up to 5 feet thick.

The mica is somewhat weathered and limonite-stained at the surface, but improves with depth. The pale reddish-brown, fresh mica books from the deeper workings were likened to the so-called ' ruby mica ' of India by Simpson (1952) who stated that " the mica is perfectly transparent throughout except for one or two very small black inclusions in about one sheet in ten ".

Finucane and Jones (1939) noted that the maximum size of mica books is about 8 inches and that pieces 6 inches x 6 inches may be cut from them. A parcel of muscovite, submitted in 1938 for examination by the Government Chemical Laboratory, was described by Simpson (1952) as being " in many-sided trimmed sheets almost all of which were free from wrinkles, cracks or twinning planes. The smallest pieces would yield sheets measuring 2 x 1 inches and the four largest sheets measuring 7 x 5, 5 x 4, 5½ x 3½, 5½ x 3½ inches respectively ". Simpson considered that this was some of the best mica ever produced in this State.

STUARTS MICA MINE

Stuarts mica mine is in a composite quartz-pegmatite dyke which crops out near the Kimberley Downs—Mondooma Road, approximately 4 miles south of Mondooma and 5½ miles north-northwest of Limestone Springs (see Plate 32). The mine was worked during 1949 as P.A. 58 for mica and beryl.

Production of 31·25 lb of muscovite valued at $A9·24, and 3·5 tons of beryl containing 38·85 units of BeO valued at $A593·40, was reported to the Mines Department. Harms (1959) reported a mica production of about 150 lb.

General geology

The composite quartz-pegmatite dyke, containing the mica deposit, intrudes a belt of basic amphibolites and garnet-muscovite schists of the Halls Creek Group. Both the dyke and metamorphic rocks trend northwest and dip southwest at 45° to 75°. A large granite porphyry of the Lamboo Complex flanks the metamorphic rocks approximately 1 mile northeast of the quartz-pegmatite.

Pegmatite workings

Pegmatite and quartz cover an area of about 15 chains by 2 chains at the deposit locality. The pegmatite phase consists of quartz, microcline, and muscovite with accessory tourmaline and beryl. The southeastern part of the dyke has been tested with pits and trenches over a length of 300 feet. The largest trench, measuring 25 feet x 10 feet x 10 feet, exposes fresh mica books mainly associated with quartz. Single crystals up to 12 x 10 inches are not uncommon. These coarse books have random orientation and in some instances are deformed at the contact with the quartz. Muscovite from other dumps and shallow surface excavations is usually weathered and limonite-stained.

Harms (1959) recorded that beryl crystals up to 6 inches wide have been recovered from this dyke although most beryl production was derived from the adjacent eluvial soils. Harms also reported that some of the beryl was semi-transparent and the better crystals might yield gem quality stones.

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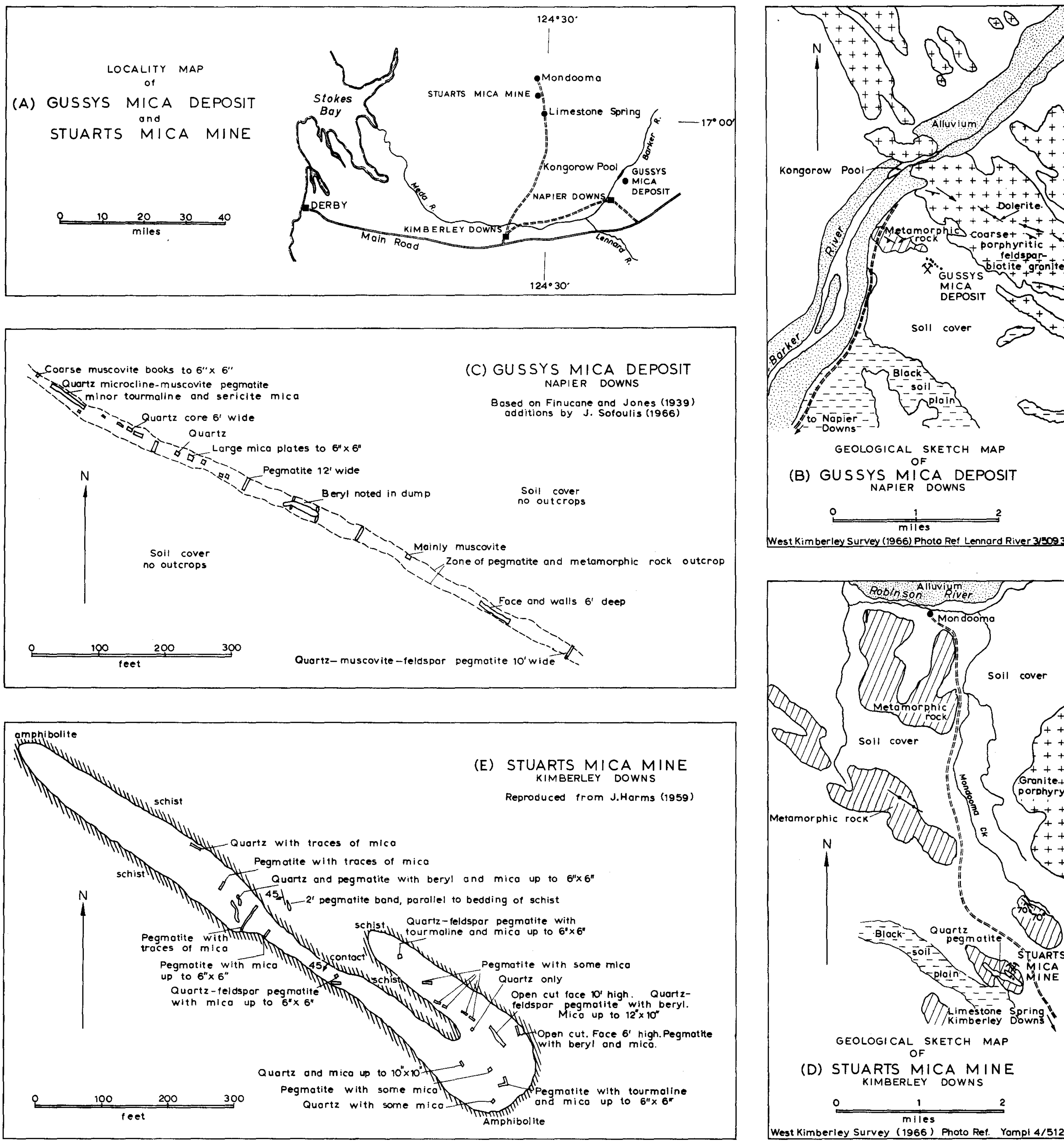
PLATE 32



GEOLOGICAL SURVEY OF WESTERN AUSTRALIA To accompany report on MICA DEPOSITS of the WEST KIMBERLEY AREA by John Sofoulis 1966

9554

THE CROCIDOLITE DEPOSITS OF MARRA MAMBA, WEST PILBARA GOLDFIELD

by J. G. Blockley

ABSTRACT

At Marra Mamba, 57·6 tons of crocidolite have been mined from three horizons within the Marra Mamba Iron Formation. These are named the Mackay Horizon, Dun Horizon, and Foxall Horizon and are respectively 140, 260, and 350 feet above the base of the formation. Only the Dun Horizon is likely to produce ore bodies of appreciable size.

Structural control of the fibre distribution is mostly obscure, but in places, crocidolite seems to have been localised by early preconsolidation folds which have been modified by later tectonic folding.

Diamond drilling preceded by structural contour mapping is necessary for further development of the deposits.

INTRODUCTION

At Marra Mamba, five deposits of blue asbestos (crocidolite) have been worked in a narrow belt extending from 3 miles west to 9 miles east of Mt. Brockman Station homestead (lat. 22° 18′ S., long. 117° 17′ E.). Marra Mamba is 80 road miles from Wittenoom Gorge and 210 miles from Point Samson. Repair of an old road through Caliwinya Gorge could reduce the distance to Point Samson to 145 miles.

The first mining tenement at Marra Mamba was pegged in 1931. Intermittent mining of the deposit between 1932 and 1942 produced 57·6 long tons of crocidolite. Although the leases have been held continuously since 1942, there has been no further production. Australian Blue Asbestos Ltd. currently holds five groups of leases and one Temporary Reserve covering the area of the deposits. All the fibre produced has been won from shallow pits and benches on the seam outcrops. There are no deep openings in the field.

The present investigation is part of a regional survey of blue asbestos in the Hamersley Range carried out between 1964 and 1966. In 1965, the area of the deposits was mapped on aerial photographs, at a scale of 20 chains to an inch, by G. R. Ryan and the writer. As a result of this work an area including Mineral Claim 61WP and Mineral Claim 62WP was selected for more detailed mapping and eventual diamond drilling. P. Muhling and the writer completed the detailed mapping in 1966, but no diamond drilling has been done yet.

Foxall (1942) and Finucane (1964 and 1965) have described the Marra Mamba crocidolite deposit. MacLeod and others (1963) and de la Hunty (1966) have related the occurrences to the regional geology. Unpublished reports on the field have been prepared by Ryan and Blockley (1965) and Australian Blue Asbestos Ltd.

REGIONAL GEOLOGY

Mapping by MacLeod and others (1963) showed the crocidolite at Marra Mamba to be in the Marra Mamba Iron Formation, the lowermost unit of the Hamersley Group. The deposits are thus stratigraphically distinct from those worked at Wittenoom and Yampire Gorges where the fibre is in the Brockman Iron Formation, and about 1,300 feet higher in the succession.

Typically, the iron formation at Marra Mamba is a banded, black, brown, and yellow rock with numerous horizons of podded chert and frequent thin partings of stilpnomelane-shale. The chert pods are often elongated in the bedding planes, with the longer axes commonly parallel to one of the major tectonic trends. Individual pods may be separated, and in sections of suitable orientation the iron formation may have the appearance of a well-bedded conglomerate.

In relation to regional structure, Marra Mamba is on the north limb of the Jeerinah Anticline (de la Hunty, 1966). The beds have an average dip of 10°N., but minor folding is common.

STRATIGRAPHY

Nomenclature and general description

Here, as elsewhere in the Hamersley Range, blue asbestos forms as cross-fibre bands parallel to the bedding of the host banded iron formation (b.i.f.). Groups of closely spaced bands have been mined as *seams*, the criterion for a seam being a payable quantity of crocidolite within a convenient mining thickness. Seams occur at several distinct stratigraphic horizons (termed *crocidolite horizons*) within the iron formation, and the presence of several such horizons with associated riebeckite rock over a given stratigraphic interval constitutes a *riebeckite zone.* Where two or more seams are present in one area, it is convenient to name them, e.g., Dun Seam, Foxall Seam, etc. The various crocidolite horizons can then be named after appropriate seams, e.g., Dun Seam Crocidolite Horizon, or Dun Horizon for brevity. A seam name then refers to one particular body of crocidolite and should not be extended further, while a horizon name applies to a certain stratigraphic position and may be used wherever the horizon can be recognized, whether or not crocidolite is present at that point.

The fibre is generally restricted to those parts of the section where the distinction between b.i.f. units and shale units is well-marked. It is associated with yellowish chert containing laminae of magnetite called *cherty b.i.f.*. *Shaly b.i.f.* (thinly bedded iron oxides, silicates, and chert) and *podded b.i.f.* (b.i.f. with well-podded chert beds usually separated by shaly material) appear to be unfavourable host rocks.

Seams have been worked at three horizons at Marra Mamba. All three are in the Marra Mamba Riebeckite Zone, the lower of the two riebeckite zones recognised in the Marra Mamba Iron Formation. The upper, or Vivash Riebeckite Zone, is not exposed in the area, but is known to contain fibre some 5 miles west of Marra Mamba. The three productive horizons have been named the Mackay Horizon, and Dun Horizon, (after two of the original discoverers) and the Foxall Horizon, after the former State Mining Engineer who first described the workings (Foxall, 1942). Recognition of these horizons is often difficult because of surface weathering and lack of marker beds, but it is important when prospecting the area.

Description of principal horizons

The Foxall Horizon has been worked on M.C. 62WP and recognized only at the eastern end of the area. Fibre of mineable grade is rare within the horizon. The horizon is about 350 feet above the base of the Marra Mamba Iron Formation. From top to bottom, a section about the fibre horizon is :

Thickness Ft.	*In.*	*Description*	
		Top	
	6	shale	
2	0	cherty b.i.f. with fibre in favourable positions	
	9	shaly b.i.f.	
3	3	podded b.i.f.	
	7	shaly b.i.f.	
	2	cherty b.i.f., finely laminated	Foxall Horizon Marker
	3	chert, yellow	
	6	shaly b.i.f.	
	4	shale, blocky weathering	
3	0	cherty b.i.f. with riebeckite and fairly persistent fibre bands.	
1	2	shaly b.i.f.	
1	0	cherty b.i.f. with fibre developed in favourable positions.	
1	0	shaly b.i.f.	
6	0	podded b.i.f.	
	9	shale.	

In the field, the Foxall Horizon is best recognized by the beds immediately overlying the most persistent fibre bands, as shown in the above table.

Dun Horizon, formerly called the "C" Horizon, is the most productive and extensive crocidolite occurrence in the Marra Mamba Iron Formation. It bears crocidolite in many places around the Jeerinah Anticline, and on the southern limb of the Mt. Brockman Syncline. The horizon is 260 feet above the base of the formation and is readily recognized by its position in the middle of a sequence of cyclic repetitions of b.i.f. and shale, also by a distinctive internal stratigraphy. A typical section about the fibre horizon is:

Thickness Ft.	In.	Description	
		Top.	
3	0	podded b.i.f.	
	9	shale.	
1	6	cherty b.i.f., sometimes with fibre.	
	3	chert, yellow, fibre developed immediately above.	
	10	shaly b.i.f.	Dun Horizon Marker
	6	cherty b.i.f., riebeckitic, develops fibre.	Dun Horizon Marker
	2 to 4	frequently two complementary fibre bands.	Dun Horizon Marker
1	3	cherty b.i.f., riebeckitic, sometimes with fibre.	
	5	b.i.f., well bedded.	
	8	cherty b.i.f., sometimes with fibre.	
1	0	b.i.f., well bedded.	
	6	shaly b.i.f.	
	6	shale.	
6	0	b.i.f., sometimes with fibre.	

The presence of the twin crocidolite bands 6 inches below the 10-inch bed of shaly b.i.f. is characteristic of the Dun Horizon.

The Mackay Horizon has been recognized only at the western end of the Marra Mamba area. Its stratigraphic position is difficult to determine, due to incomplete exposure, but the adjacent succession of rocks resembles that about the "A" Horizon (see below). Ryan and Blockley (1965) equated it with the Dun Horizon, but this correlation is now considered invalid. On M.C. 65WP, the Mackay Horizon contains the most spectacular development of fibre seen at Marra Mamba, with grades ranging up to 7 inches over a 6-foot seam thickness. A typical section is:

Thickness Ft.	In.	Description	
		Top.	
	3	shale.	
1	7	b.i.f.	
	3	shale.	
3	2	b.i.f.	
4	4	cherty b.i.f. with fibre	Mackay Horizon
1	3	shaly b.i.f.	Mackay Horizon
2	10	cherty b.i.f. with fibre	Mackay Horizon
1	2	shaly b.i.f.	
	4	shale.	
14	4	b.i.f.	

The shaly b.i.f. in the middle of the seam is similar to that in the Dun Horizon, but the absence of the twin fibre bands, and the different spacing of the surrounding shales, serves to distinguish the two horizons.

Other crocidolite-bearing horizons include one containing up to 4 inches of fibre over 2 feet seam thickness exposed in three gorges between M.C. 62WP and M.C. 64WP. It is about 120 feet below the Dun Horizon and comprises three bands of fibre within a 2-foot thick chert bed which in turn is part of a 12-foot thick b.i.f. unit. Because of the low stratigraphic position, few gorges have been cut deeply enough to expose the horizon. No fibre has been won from this seam, which is provisionally called the "*A*" *Horizon.* As stated above, it may be equivalent to the Mackay Horizon.

Other low-grade seams of apparently small extent have been seen at positions 85 feet and 60 feet below, and 30 feet and 47 feet above the Dun Horizon, and at 35 feet above the Mackay Horizon.

STRUCTURE

Folding

Minor folds are common at Marra Mamba and mapping has revealed two types. The earlier folds trend nearly east-west between 260° and 290°. These may change direction and usually die out within a short distance along strike. Crumpling is common in the limbs, and the north-dipping limbs are often steep, even being overturned in places. These folds may appear abruptly in evenly dipping strata and usually only a small area is involved in the folding. It would seem that the rocks were incapable of transmitting stresses over any great distance during folding.

Probably these structures represent 'flow-folds' (Billings, 1942, p. 87) and were caused by the sliding of incompletely consolidated beds northwards from the rising Jeerinah Anticline, in the early stages of regional folding. A few monoclines which face northwards were probably formed in the same way.

The later and more intense folds control the form of the outcrop, and trend at 300°. Their south-dipping limbs are the shorter, indicating a normal drag-fold relationship with the Jeerinah Anticline. Many folds can be traced for several thousands of feet and are in wide belts, suggesting that the causative stresses were transmitted through a considerable body of rock. It is believed that these folds are of tectonic origin and were formed during the period of Ophthalmian folding (Halligan and Daniels, 1964).

Faulting

Most faults at Marra Mamba trend either northwest or northeast and have little displacement. They may contain weathered dolerite dykes, as do many faults with similar trends elsewhere in the Hamersley Range. Towards the eastern end of the area shown on Plate 33, a fault trending west-northwest displaces the beds a few hundred feet laterally but the vertical component is unknown.

Structural control of crocidolite distribution

Two deposits of crocidolite at Marra Mamba have obviously been controlled by structure. The first is on M.C. 65WP where the Mackay Horizon has 7 inches of fibre on a 'flow-fold' anticline, but is poor or barren elsewhere. The second occurrence is about 4,000 feet southeast of M.C. 61WP where fibre has developed in two horizons on the steeply dipping north face of a monocline. The fibre is absent where the dips flatten to the north and south.

Structural control is less apparent at other deposits, but since the fibre often occurs at changes in dip on the limbs of tectonic folds, it is possible that earlier folds may have been incorporated into later structures in these situations. An example of this is the Foxall Horizon on M.C. 62WP (Plate 34) where the fibre grade is higher at a sharp dip change on the north limb of a small anticline.

DESCRIPTION OF CLAIMS

M.C. 61WP

This claim covers the easternmost group of workings where the productive seam is in the Dun Horizon. Recorded production from this deposit is 47·55 tons. Mining was restricted to the northern part of the outcrop where the seam contains aggregate fibre lengths of up to 2½ inches over about 2 feet seam thickness. Benches extend continuously for 500 feet along the eastern side of the gorge and intermittently for the same distance on the western side.

The Dun Horizon was also mined in another branch of the gorge 1,200 feet to the southwest. Here, benches extend 250 feet along the cliffs on the western side of the ravine. Fibre grades range 2 to 3 inches over 2 feet seam thickness.

There is little evidence for structural control of crocidolite distribution on M.C. 61WP, although the fibre is restricted to the more steeply dipping beds. Slight warps trending across the strike are shown by the structural contours on Plate 34, and may have helped to localize the fibre.

M.C. 62WP

Mining on M.C. 62WP was restricted to a lens of spectacular growth of fibre on the Foxall Horizon where exposed for a length of 150 feet on a low bluff. The seam dips northwards below creek level and still contains oxidized fibre at this point. To the south of the workings however, the fibre is low-grade and patchy. Although the outcrop of the horizon was traced for some thousands of feet in the gorges to the south and west, no further rich seams were found.

PLATE 33

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PLATE 34

GEOLOGICAL SURVEY OF WESTERN AUSTRALIA
STRUCTURAL CONTOUR MAP
MINERAL CLAIMS 61WP & 62WP
MARRA MAMBA CROCIDOLITE AREA
PLANE TABLE & ALIDADE SURVEY
BY J. BLOCKLEY & P. MUHLING. JULY 1966.
TO ACCOMPANY REPORT BY J. BLOCKLEY. 1966.
REFERENCE
CROCIDOLITE HORIZON – WITH CONTINUOUS FIBRE
CROCIDOLITE SEAM – BENCHED
CROCIDOLITE HORIZON – PATCHY FIBRE
CROCIDOLITE HORIZON – FIBRE ABSENT
STRUCTURAL CONTOUR ON DUN HORIZON
STRUCTURAL CONTOUR ON FOXALL HORIZON
LAND SURFACE CONTOUR
TRACKS
WATER COURSE
AXIS OF SYNCLINE
AXIS OF ANTICLINE
AXIS OF MONOCLINE (DOUBLE ARROW SHOWS STEEPER DIPS)
SURVEY STATION WITH SPOT HEIGHTS
(DATUM FOR HEIGHTS AND CONTOURS: STATION A = 2000 FEET)
ESCARPMENT
NORTH (MAGNETIC)
SCALE IN FEET
200 0 200 400 600 800
MC 62WP
MC 61WP
(INCLUDES MCS 21 & 43)
STEEL PEG
A (ASSUMED DATUM 2000')
FOXALL HORIZON DATUM
FOXALL HORIZON
DUN HORIZON
"A" HORIZON
FOXALL SEAM
DUN SEAM
SCALE IN FEET
BASE OF MARRA MAMBA IRON FORMATION
STRATIGRAPHIC COLUMN
KEY TO STRATIGRAPHIC COLUMN
BANDED IRON FORMATION (B.I.F.)
SHALEY B.I.F.
B.I.F. WITH PODDED CHERTS
SHALE
CROCIDOLITE HORIZON

Foxall (1942) quotes an assay from the seam as 9 to 10½ inches over 8 to 8½ feet. However, the overall average is nearer 5 inches over 10 feet. Recorded production from this seam is 0·15 tons. The enrichment is on the northern limb of an anticline at a place where the dip steepens from 15° N to 30° N.

M.C. 63WP

The area of M.C. 63WP includes two groups of workings in adjacent gorges, both exploiting a seam in the Dun Horizon.

In the western gorge, the seam has been benched for about 250 feet along its outcrop. The workings start at creek level and extend southwards into the cliffs on the eastern side. The fibre grade ranges up to 3 inches over 2 feet. To the south there is a nearly blank zone of 350 feet, but values improve again on a monocline. Oxidized fibre can be traced eastwards from the southern end of the exposure into the next gorge. Here the seam has again been mined on the eastern side of the gorge with the diggings extending intermittently for 500 feet along the outcrop. Fibre grades of 3 to 4 inches over 2 feet seam thickness are common, and the seam is still of good tenor where it dips below creek level. Another seam 30 feet above the Dun Horizon has also been trenched for a short distance.

The better fibre on M.C. 63WP is located on the steeper dips of a gentle monocline.

M.C. 64WP

On M.C. 64WP the Dun Horizon can be traced for about 800 feet along the cliffs, but contains significant fibre only where it has been mined at the head of the gorge. Aggregate fibre length does not exceed 2 inches over 2 feet and only a little work has been done. A fault close to the benches has displaced the horizon a few feet vertically. Any relationship of fibre to structure is obscure.

M.C. 65WP

This claim contains the only workings on the Mackay Horizon. Although the horizon can be traced for about 1,000 feet along the gorge, mining was restricted to the limbs of an anticline of the 'flow-fold' type where there is a spectacular enrichment of crocidolite. This enrichment has been benched on the western side of the gorge and on a spur at the junction with an eastern tributary. Fibre grades reach 7 inches over 6 feet seam width on either side of the anticline's crest, but decline appreciably further from the fold axis.

CONCLUSIONS

1. Of the three chief crocidolite horizons at Marra Mamba, only the Dun Horizon seems likely to contain deposits of an appreciable size. It is expected that the grade of any such deposit would be marginal, say 2½ to 3½ inches over a normal stoping width. The Foxall and Mackay Horizons contain spectacular enrichment of small size, but are generally too low-grade to be considered as mining propositions.

Due to lack of continuous exposures, no estimate of the potential of the " A " Horizon could be formed. However, it is thought to be stratigraphically equivalent to the Mackay Horizon.

2. The origin of blue asbestos in iron-formation is not yet fully understood. Cilliers and Genis (in press) and Trendall (1966) have demonstrated that it is a late-stage diagenetic mineral. The first authors speculated that colloids of riebeckitic composition, migrating into early structures, controlled the distribution of the fibre. Trendall showed that riebeckite replaces the cherts of the iron-formation, suggesting that sodium (the only additional constituent needed to convert b.i.f. to riebeckite or crocidolite) was introduced in solution.

At Marra Mamba it seems that the sodium-rich solution (or gel?) was concentrated in early folds formed by the sliding of the unconsolidated iron formation off the rising Jeerinah Anticline. These structures have been obscured by later tectonic folding.

3. Attempts to develop the Marra Mamba crocidolite deposits will face the following problems :

a. individual deposits are small and considerable exploration would be required to keep up ore reserves ;

b. the fibre is associated with riebeckitic cherts which may give milling problems ;

c. folding of some deposits would raise mining costs ;

d. many of the known deposits are too close to the surface to be mined safely by underground methods.

These difficulties suggest that a rise in the price of crocidolite may be necessary before the Marra Mamba deposits can be worked profitably. However, with the rapid development of the Pilbara iron-ore deposits, the problems of remoteness and labour shortage in the North may become less acute, so reducing one of the obstacles encountered in past attempts to exploit these deposits.

4. As any mining operation would probably be based upon the deposits within the Dun Horizon, the first step in developing the field would be to evaluate one or more of these by diamond drilling. Those seams worked on M.C. 61WP and M.C. 63WP would be suitable, as both extend some distance along strike and still carry fibre where they dip below creek level. This drilling would best be preceded by structural contour mapping such as has been done on M.C. 61WP. The holes should penetrate at least as far as the " A " Horizon in order that all the known horizons should be tested.

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COLUMBITE–BERYL DEPOSIT ON MINERAL CLAIM 313, PILBARA GOLDFIELD, AND ITS SIGNIFICANCE

by H. A. Ellis*

ABSTRACT

Production of economic minerals from pegmatites in Western Australia has mainly been from intrusions into Archaean greenstones. An occurrence of beryl and columbite, where the pegmatite host intrudes granitic rocks is described from a locality about 22 miles southeast of Port Hedland.

Because granitic rocks have not proved to be favourable hosts for gold mineralization, such areas have been largely neglected by prospectors. In view of the described rock association however, pegmatites intruding granitic rocks should now be more closely examined.

INTRODUCTION

Mineral Claim 313 is situated about 22 miles southeast of Port Hedland, and about 9 miles southeast of Pippingarra homestead on Pippingarra Station, at approximately latitude 20° 35′ S. and longitude 118° 46′ E. The position of the workings is shown by a convential mine sign on the 4 miles to one inch Port Hedland Topographical Sheet published by the Lands Department.

GEOLOGY

When first examined by the writer in July 1955, work done since discovery in about 1953 indicated a decomposed mass of pegmatitic material striking N. 60° E. with an unascertainable dip. The pegmatite occurs in a low ridge with three conspicuous knolls of white quartz, surrounded by flat, brown, sandy spinifex country with no sign of any greenstone. The pegmatite appears to be emplaced in a granitic terrain and its approximate dimensions are from 500 to 600 feet wide and 60 chains long.

A lower section at the northeastern end of the claim is much more decomposed than other sections and was the main producing area. Here, eluvial columbite and beryl are in red clay loam some 2 feet thick, changing at that depth into partially decomposed dyke material. This material contains muscovite plus feldspar, and muscovite plus quartz concentrations, with a prominent distribution of pale blue quartz in both assemblages.

Numerous lenses of muscovite were noted with plates up to 2 inches wide, but a fine scaly development was much more common. Some beryl was seen in situ in association with the white scaly muscovite but no columbite was seen in situ. Much albite feldspar, some microcline feldspar, numerous quartz masses, and some pale-coloured scaly lepidolite were also noted in the area being scraped by a small bulldozer. The deepest excavation at the time of inspection was only 8 feet, and no systematic attempt had been made to define either the limits of the pegmatite dyke or the boundaries of the beryl and columbite bearing zones.

There were not enough exposures available to determine the zones in which the beryl and columbite occurred, but from the reported localities of the richest eluvium, it appeared that those zones near or adjacent to the larger quartz masses were the main producers.

A specimen of columbite ore weighing about 15 lb seen at the treatment plant 1 mile southwest of the workings, consisted of columbite, fine-grained albite, quartz granules, and brown coarsely lamellar albite (' curly albite '). The size of the columbite in the eluvium ranged from wheat grain size to places up to 2 inches square and ½ inch thick.

Two specimens of columbite from this locality showing some crystal faces, one weighing 13 lb 4 oz and the other 9 lb, (the latter obviously a twinned crystal), were seen at Pippingarra homestead. No large crystals of beryl were seen ; the largest size of the pieces of beryl in the eluvium are reported as being approximately 6 inches by 3 inches by 2 inches.

PRODUCTION

The first recorded production was in 1953 and the last in 1957. During this period 60·54 tons of beryl containing 718·23 long ton units of BeO valued at $A21,508·7 F.O.B. were reported as coming from the deposit (Table 1).

In the same period 6·55 tons (14,769 lbs) of columbite valued at $A20,824·3 F.O.B. were produced (Table 2). Reliable assay data for all of this production are not available, but there are some assay data which are useful as a guide to the grade of the columbite mined and assayed " as received " by the buyer.

Table 1

BERYL PRODUCTION FROM MINERAL CLAIM 313

Year	Ore tons	BeO units long tons %	Est. Value F.O.B. $A
1953	7.61	85.18	2,555.4
1954	9.77	112.17	3,364.9
1955	43.16	520.88	15,588.4
Total	60.54	718.23	21,508.7

Note.—Production after 1955 not available, sales credited to Crown Lands, Marble Bar District generally.

Table 2

TANTO/COLUMBITE PRODUCTION FROM MINERAL CLAIM 313

Year	Ore & Concentrates lb.	ASSAY			Metallic content TaNb units	Est. Value F.O.B. $A
		Ta %	Nb %	TaNb Combined Oxides %		
1953	3,654	8.52	65.52	74.04	120.78	9,960.0
1955	1,151	10.85	59.80	70.65	36.30	2,942.5
	329	Not	stated	73.95	10.84	876.6
	867	Not	stated	73.77	28.52	2,406.0
1957	3,701	20.51*	43.05*	73.56*	105.00	1,056.0
	3,107	20.51*	43.05*	73.56*	88.17	1,649.2
	1,870	Not	stated	66.82	55.75	1,034.0
Total	14,769lb. or 6.55 tons				445.36	20,824.3

* Not true assays—material bulked in with other parcels for sale purposes and overall average applied as basis of payment.

Concentrates reported for 1953 amounted to 3,654 lb containing 8·52% Ta_2O_5 and 65·52% of Nb_2O_5 (combined oxides 74·04%) and another parcel of 1,151 lb of concentrates reported for 1955 contained 10·85% Ta_2O_5 and 59·80% Nb_2O_5 (combined oxides 70·65%).

The lowest figure for combined oxides in the production data is 66·82% and the highest 74.04%.

The average BeO content of the 60·54 tons of beryl was 11·86%, a normal figure for this part of the State.

ENVIRONMENT OF THE DEPOSIT

Throughout Western Australia, the pegmatites occur in rocks of presumed Archaean age, and are nearly always transgressively intrusive into greenstones in the case of those carrying columbite and tantalite. This is noticeably

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the case in the Pilbara and West Pilbara Goldfields in the northwestern part of the State, examples being Wodgina, Tabba Tabba, Strelley, and Pilgangoora, all within a radius of 50 miles of the M.C. 313 occurrence.

No outcropping greenstones are known in the locality of M.C. 313, and the limited exposures of the surface eluvial mining operations on this claim at the time of inspection did not reveal any traces of these rocks. The nearest greenstone occurrences known to the writer are at Tabba Tabba, some 12 miles to the southeast.

It appears that this columbite-bearing pegmatite mass has granite or granitised rocks as its host rock.

For many years, the country for 80 miles or so south of Port Hedland, which is predominantly granitic (either massive or schistose) in nature, has been the source of considerable quantities of eluvial beryl, reported in the Mines Department statistics as from ' Crown Lands '. There is a strong development of white quartz as both hills and ridges in this area, and the eluvial beryl occurs in the vicinity of these quartz masses. The writer has seen localities here where beryl has been mined from the edge of a large quartz mass, from 3 to 18 tons being obtained from several occurrences.

It is possible that small quantities of eluvial columbite or even tantalite may have been won from this general area and traded by natives or prospectors to the owners of producing claims at Wodgina, Tabba Tabba, Strelley, and Pilgangoora, but no holdings are known to have been previously taken up in the area away from the greenstones.

POTENTIAL OF GRANITISED ZONES

The above occurrence is a good example of the potential of a granitised zone, and another one is the mica-beryl Yinnietharra locality some hundreds of miles to the south. The cassiterite and high-grade tantalite-bearing pegmatitic developments in granitised rocks almost adjacent to unreplaced greenstone bands at Greenbushes are yet another example.

Many of the most productive columbite—tantalite—beryl-bearing pegmatite dykes so far worked in Western Australia have been found, however, in transgressively intrusive pegmatite dykes with greenstones as host rocks. In addition to the Wodgina, Strelley, Tabba Tabba, and Pilgangoora localities, the following come readily to mind:

Location 6 miles southeast of Roebourne
Londonderry feldspar quarry (south of Coolgardie)
Beryl—columbite claims at Spargoville (south of Coolgardie)
Ravensthorpe pegmatites at Cattlin Creek
Poona locality and Kathleen Valley (south of Wiluna).

Discoveries in the greenstone belts are expected to be more frequent because it is in this environment that prospecting for gold has been most active. The granitic terrain, much of which is actually granitised greenstone, has not been attractive to gold prospectors. Its potential for beryl, columbite, tantalite, and cassiterite is sufficiently important to warrant a special effort being made in regional mapping to indicate this class of rock whenever possible, in a clear manner on the maps, and to stress its mineral potential.

A NEW CRANIACEAN BRACHIOPOD FROM THE TERTIARY OF WESTERN AUSTRALIA

by A. E. Cockbain

ABSTRACT

Westralicrania allani gen. nov. et sp. nov. is described from Palaeocene strata in Denham 2 bore, Shark Bay.

INTRODUCTION

The Denham water supply bore (Denham 2) was sited behind the Water Supply building in Knight Terrace, Denham, on Peron Peninsula, Shark Bay. Full details of the bore are on file at the Geological Survey of Western Australia. The sequence penetrated is similar to that already established in other bores in the Shark Bay area (Konecki and others, 1958, Plate 5).

The sample from which the new species was recovered consisted of well cuttings from a depth of 520 feet. Other fossils recorded from this sample include numerous cyclostomatous and cheilostomatous bryozoans, cytheraceid ostracods, *Bairdia* sp., *Discorbis* cf. *midwayensis*, *Vaginulina longiforma*, and *Guttulina problema* species group. The foraminifera suggest a Palaeocene age and the sample comes from part of the Cardabia Group, most probably the Pirie Calcarenite (Condon and others, 1956, p. 36).

SYSTEMATIC PALAEONTOLOGY

Phylum:	Brachiopoda
Class:	Inarticulata
Order:	Acrotretida
Suborder:	Craniidina
Superfamily:	Craniacea
Family:	Craniidae

WESTRALICRANIA gen. nov.

Genoholotype: *W. allani* sp. nov.

Diagnosis

A genus of Craniidae with a flat ventral valve with mixoperipheral growth and a convex dorsal valve with holoperipheral growth; internally the ventral valve bears a short median ridge.

WESTRALICRANIA ALLANI sp. nov.
(Plate 35)

Diagnosis

A species of *Westralicrania* with short spines scattered over the surface of both valves. The species is named in honour of the writer's former colleague, the late Professor R. S. Allan.

Material

Seven nearly complete ventral valves, 3 nearly complete dorsal valves, 15 incomplete ventral valves. 3 incomplete dorsal valves.

Dimensions

Specimen No.	Valve	Length (mm)	Width (mm)	Thickness (mm)
F 6102/1	Ventral	6.8	7.0	0.8
F 6102/2	Ventral	2.6	2.2	0.3
F 6102/3	Dorsal	2.2	2.5	0.7
F 6102/4	Dorsal	3.2	3.4	0.9
F 6102/5	Ventral	5.6	5.7	0.6
F 6102/6	Ventral	3.9	3.8	0.5
F 6102/7	Ventral	4.2	4.2	0.5
F 6102/8	Ventral	4.9	5.0	0.6
F 6102/9	Ventral	4.2	3.9	0.6
F 6102/10	Dorsal	4.0	4.0	1.0

Description

The holotype is a ventral valve (F 6102/1; Plate 35A).

The exterior of the valve is almost round and wider than long; nearly straight anterior margin, gently curved laterally and posteriorly;

roundly triangular umbonal region; posterolateral angles not marked; valve very slightly convex at margins, more or less flattened centrally; growth mixoperipheral with apsacline pseudointerarea; ornamentation consists of concentric growth lines and irregularly scattered pustules which are slightly elongate radially and may develop into short spines.

The interior has a wide limbus which is separated posteriorly from the pseudointerarea by a very narrow raised rim; the limbus is ornamented with small pits which tend to be concentrically and regularly arranged distally and more irregular proximally; within the limbus the valve is slightly concave; a strong but short median ridge arises in the centre of the valve. There are two pairs of muscle scars. Except for the ridge and muscle scars the interior surface of the valve is covered with irregularly arranged pits. The posterior adductor scars cut back into the limbus so that it is narrow opposite them; the scars are widely spaced. The anterior adductor scars are close together on either side of the median ridge. A slight U-shaped depression embraces the median range; three small ridges separate shallow radial depressions on either side. These depressions are taken to represent the position of the vascula lateralia.

The paratype is a ventral valve (F 6102/4; Plate 35B).

The exterior is nearly round in outline with curved anterior and lateral margins and straight posterior margin; posterolateral angles obtuse. Growth is holoperipheral and the valve is conical, with the umbo about one-quarter of the diameter from the posterior margin. Ornamentation consists of concentric growth-lines and irregularly scattered short spines.

In the interior the limbus is feebly developed except posteriorly where it is widest; elsewhere it is hardly differentiated from the interior of the valve. The valve is markedly concave, the greatest depth being immediately in front of the posterior limbus. The interior of the valve is ornamented with numerous pits which are irregularly arranged. The two pairs of muscle scars are smooth raised areas. The posterior adductor scars are round and widely spaced, and cut into the limbus at the posterolateral angles of the valve; they are slightly below the level of the limbus. The anterior adductor scars are elongated antero-posteriorly, close together, and situated just anterior to the greatest depth of the valve. In front of them in the midline is a very low median swelling.

Ontogeny of ventral valve

The smallest specimen (F 6102/2; Plate 35C) is elongate triangular, tapering posteriorly to the umbo. Mixoperipheral growth is marked and the pseudointerarea is one-fifth of the total length of the valve and nearly orthocline. The exterior is ornamented with concentric growth lines and scattered spines. The limbus is broad and radially striated distally; proximally it is irregularly pitted as is the rest of the interior of the valve. Two pairs of muscle scars are arranged as previously described. The median ridge is long and low and extends from the anterior edge of the anterior adductor scars to the midline of the posterior adductor scars.

Other specimens show that as the ventral valve increases in size the pseudointerarea becomes proportionately smaller and more apsacline. Interiorly the median ridge becomes higher and shorter until in the adult it extends between the posterior adductor scars only as a low swelling. As growth proceeds the ornamentation of the limbus changes. The early radial striae become confined to the distal edge or are lost completely, and the limbus is ornamented with concentric or irregularly arranged pits. The external ornamentation consists of well-marked short spines in the young stages. Later the shell thickens and the spines appear as pustules. The earliest growth stages (up to about 1 mm) have very few or no spines. In some specimens the smooth umbo is flattened or slightly concave suggesting attachment to some object. Whether the animal was attached throughout life or only when young is impossible to determine.

Ontogeny of dorsal valve

The smallest dorsal valve (F 6102/3; Plate 35D) differs from the large valves only in size, in the lack of even a slight median swelling, and in having the limbus distally striate.

The few incomplete specimens of dorsal valves show that as the valve becomes larger the posterior portion of the limbus increases in size, especially between the posterior adductor scars. The median swelling never becomes very large but seems to be variable in its development: it is a low swelling in some specimens and a slight ridge in at least one specimen.

REMARKS

The genus *Westralicrania* most nearly resembles *Crania* from which it differs in the strong mixoperipheral growth of, and median ridge in, the ventral valve. *Isocrania* has a conical ventral valve. The dorsal valve in all three genera is very similar in that it is conical and lacks internal processes. This serves to separate these genera from all other post-Palaeozoic craniaceans which possess such processes in the dorsal valve.

The only other Tertiary craniacean known from Australia is *Ancistrocrania skeatsi* Allan, 1940 (= *Crania quadrangularis* Tate) from the Oligocene of Victoria. The writer has been able to examine stereoscopic photographs of Allans's figured topotype; it is distinct from *Westralicrania allani* in shape and ornamentation, and, since it does not possess well developed apophyses, probably is not referable to *Ancistrocrania*.

ACKNOWLEDGEMENTS

I wish to thank Professor M. Gage of the University of Canterbury, New Zealand, for making available photographs of Allan's topotype of *A. skeatsi.*

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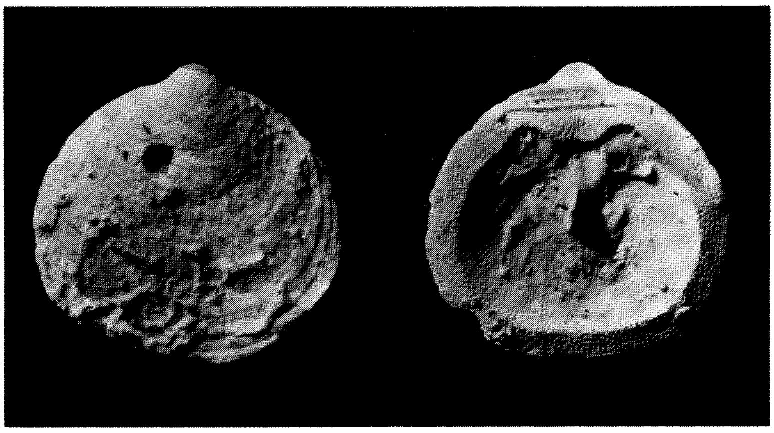
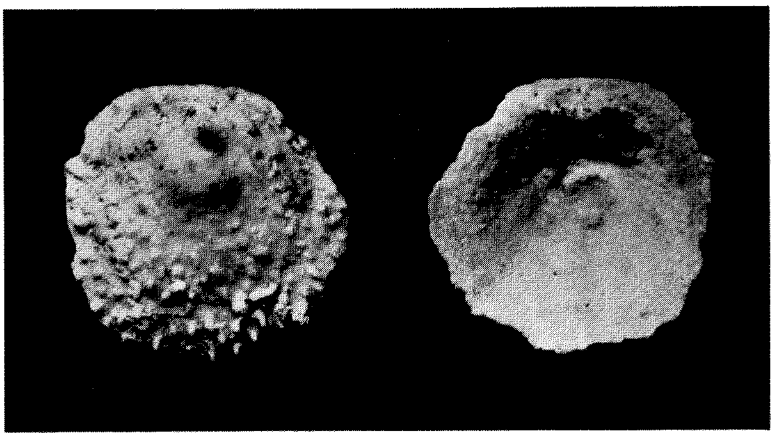
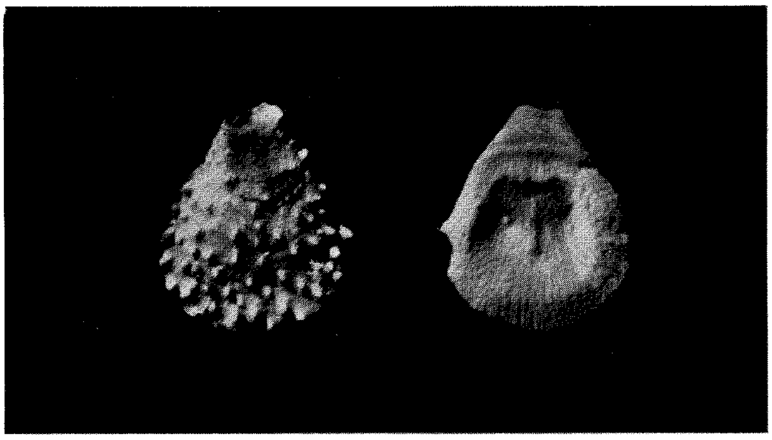
WESTRALICRANIA ALLANI gen. nov. et sp. nov.



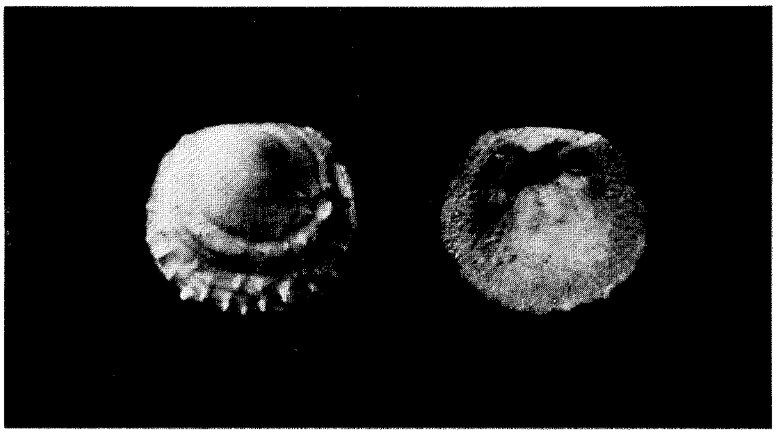
A—Holotype ; external and internal views of ventral valve ; F 6102/1, x6.



B—Paratype ; external and internal views of dorsal valve ; F 6102/4, x12.



C—External and internal views of a small ventral valve ; F 6102/2, x12.

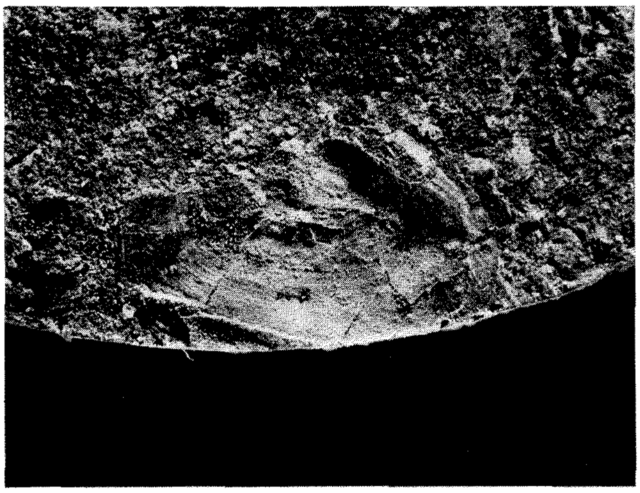


D—External and internal views of a small dorsal valve ; F 6102/3, x12.

PLATE 36

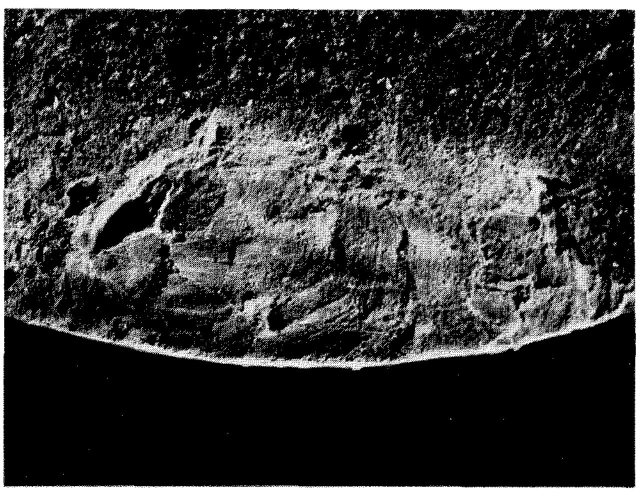
UNIONACEA gen. et sp. indet.

A—Right valve, shell material carbonised; F 6140/2A, x5.



B—Left valve, external mould; F 6140/3A, x5.

C—Left valve, shell material carbonised F 6140/3B, x5.



PELECYPODA FROM THE YARRAGADEE FORMATION

by A. E. Cockbain

ABSTRACT

Indeterminate unionacean pelecypods are illustrated from the Yarragadee Formation encountered in Gingin Brook 6 bore.

INTRODUCTION

Half a dozen fragments of a pelecypod have been found in core 13 (2,600 to 2,610 feet) from Gingin Brook 6 bore during hydrogeological investigations in the Gingin area. The core consists of dark grey siltstone with irregular sandy patches and comes from the Yarragadee Formation. The microflora from this bore belongs to Ingram's zone B of probable Neocomian age (Ingram, 1967). Molluscs have been recorded previously from the Yarragadee Formation by Mr. S. P. Willmott of WAPET but have not been illustrated.

SYSTEMATIC PALAEONTOLOGY

Phylum :	Mollusca
Class :	Pelecypoda
Superfamily :	Unionacea

UNIONACEAN gen. indet, et sp. indet.

Description

The fossils are preserved as thin carbonaceous films showing the external ornamentation. The description is based on an examination of the shell and external mould of the two most complete specimens.

The largest fragment (Plate 36A) has most of the posterior end missing. A somewhat smaller and more complete shell (Plate 36B and C) is 10·5 mm long and has a height of 7 mm. The valve is oval in lateral view with the umbo one third of the length from the anterior end of the shell. The anterior end is gently curved whilst the posterior end is straighter, meets the hinge line at an obtuse angle, and curves sharply into the ventral margin. The valves are slightly convex but there has been some flattening and fracturing of the shell during fossilization. The ornamentation consists of growth lines (6 per mm measured on the mid-ventral portion of specimen No. F 6140/2A) and coarser concentric wrinkles which are irregularly spaced but average about 1 mm apart.

Remarks

The specimens available are too poorly preserved to determine generically. They almost certainly belong to the fresh and brackish water mussel superfamily Unionacea. The lack of surface sculpture suggests that the shells may be mutelids rather than unionids although the material is not closely comparable with any of the Australian fossil unionaceans figured by Newton (1915), McMichael (1957), or Ludbrook (1961). A complete determination must await the discovery of less fragmentary material.

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A PRELIMINARY PALYNOLOGICAL ZONATION OF THE YARRAGADEE FORMATION IN THE GINGIN BROOK BORES

by B. S. Ingram

ABSTRACT

Three preliminary palynological assemblage zones are suggested within the Upper Jurassic —Lower Cretaceous strata of the Yarragadee Formation encountered in the Gingin Brook bores. The problems of correlation, both local and regional, of this formation are briefly discussed.

During 1965–66 the Geological Survey drilled the Gingin Brook line of bores across the Perth Basin, approximately along the latitude of the town of Gingin. Cores taken in all six bores were examined for their spore and pollen content. This examination suggested a threefold palynological zonation of the Upper Jurassic—Lower Cretaceous strata of the Yarragadee Formation which predominates in the sections encountered. The occurrence of these zones is shown on the accompanying diagram (Figure 16).

The incentive to search for palynological zonation of these strata comes from the amount of drilling for underground water information being carried out by the Mines Department in the Perth Basin. A more accurate palynological correlation of the Yarragadee Formation than is available would be extremely useful. In fact, the only published work on Western Australian spores and pollen grains of this age is the preliminary paper of B. E. Balme (1957). Balme (pers. comm. 1966) now uses subdivisions within the broad zones postulated in 1957 but they are still completely informal. The lack of sustained interest is due mainly to the dominantly continental nature of the Yarragadee Formation and hence its lack of oil potential. However, for a complete understanding of the hydrogeology of the Perth Basin, a detailed knowledge of the Yarragadee Formation is essential.

Palynology is probably the only practicable method available for correlation and zonation because of the otherwise unfossiliferous nature of the continental sediments, the impersistent lithologies, and lack of distinctive electrical logging characteristics. The great thickness of sediment represented (e.g. over 10,000 feet in WAPET's Gingin No. 1 well), and lack of diverse microfloral assemblages add further complications.

In the early stages of this work, problems were encountered by trying to correlate Western Australian zones directly with the European stages. Later it became apparent that this broad correlation is very difficult to make at the present state of knowledge, and furthermore it appears that two different interpretations of Australian palynomorph assemblages are being used. There is some evidence from

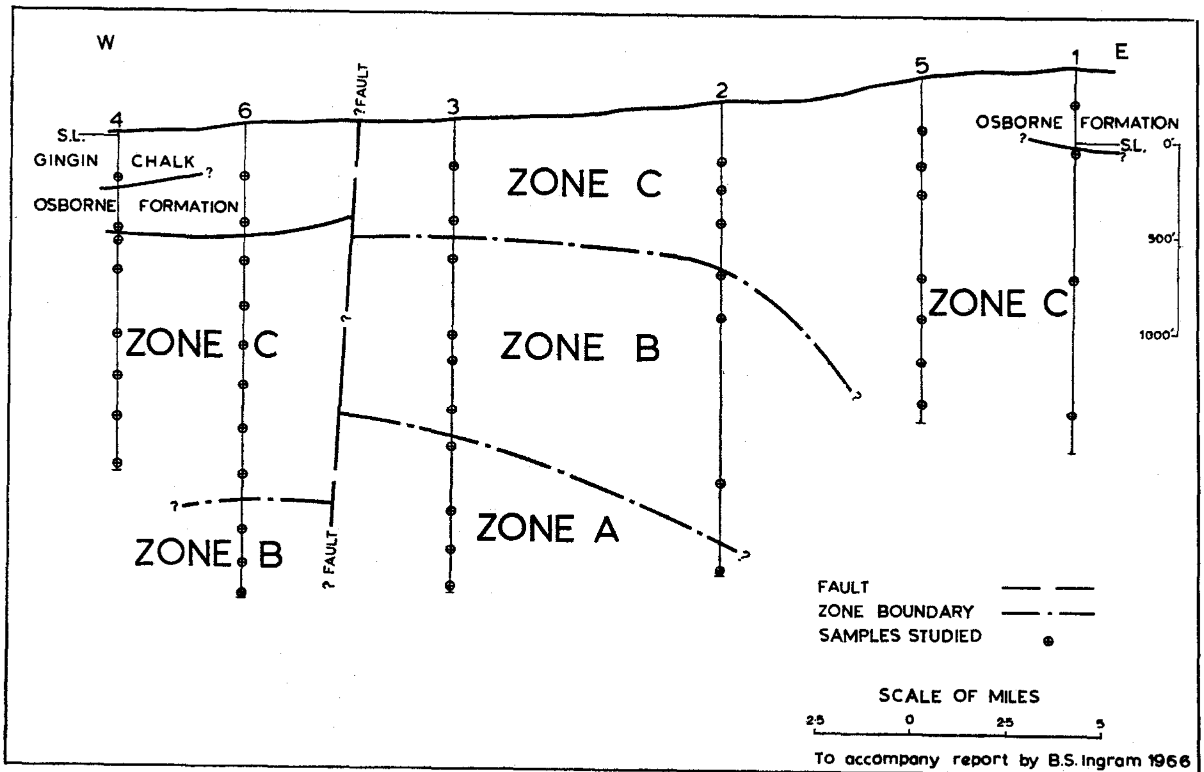

FIGURE 16– CORRELATION OF TENTATIVE UPPER JURASSIC—LOWER CRETACEOUS PALYNOLOGICAL ZONES IN GINGIN BROOK BORES

Evans' (1965) work that eastern Australian assemblages are considered to be about one stage lower than their suspected Perth Basin equivalents, within upper Jurassic—Lower Cretaceous strata. This can be seen in the chart below, summarizing the zonation. This possible discrepancy may be because of the lack of detailed stratigraphic work on the Western Australian section rather than a true time lag (i.e., the slow migration of floras from east to west). However the three zones, whatever their geological stage status, are still considered useful for local correlation.

As the zones are preliminary, they are described only in general terms.

Zone A, the oldest assemblage encountered, occurs low in Bores 2 and 3. It is restricted in types, containing mainly gymnospermous pollen with very rare spores, and long-ranging forms such as *Cyathidites australis* Couper and *Baculatisporites comaumensis* (Cookson). The restricted nature of the assemblage makes it difficult to use but it has been considered to occur only in the uppermost Jurassic—lowermost Cretaceous portion of the Yarragadee Formation. Evans' (1965) J4 (or J5) zone appears to be similar, and hence this zone is considered most likely to be of Jurassic age.

Zone B is found in Bores 2, 3, and 6. The assemblage is still dominated by gymnospermous pollen but with a slightly larger variety of spores including the first occurrence in the Gingin bores of *Contignisporites* and *Foveosporites*. Such an assemblage is being considered in the Perth Basin as probably lowermost Cretaceous or possibly uppermost Jurassic (hence the ?Neocomian assignment) but its resemblance to Evans' J5 zone suggests this may also be Jurassic.

Zone C, the youngest, occurs in all bores. The assemblage is much more diverse, and contains many more spore genera including *Murospora*, *Laevigatosporites*, *Trilites*, *Trilobosporites*, and *Cicatricosisporites*. Variations were noted within this assemblage and it is considered detailed work would allow further subdivision. Unfortunately not enough of Dettmann's (1963) diagnostic species have been identified to allow firm correlation with her assemblages. In terms of Evans' zones this assemblage would appear to include parts of J5 and K1a. Thus it is possible that this zone also includes some Upper Jurassic strata although it has been considered as definitely Lower Cretaceous (Neocomian—Aptian) in the Perth Basin. Rare microplankton in a few samples from this zone in Bores 4 and 6, although poorly preserved could be worth further investigation to allow some check on the spore and pollen evidence.

It is encouraging that the proposed zones generally agree with the stratigraphy and structure of the area as described by Sanders (1967). However it must be emphasized that the zones are preliminary and at present of only local significance.

SUMMARY OF ZONATION

		Zone A	Zone B	Zone C
Preliminary zones of Yarragadee Formation, Gingin Brook bores		Zone A	Zone B	Zone C
Current terminology in W.A.		Tithonian-Neocomian	? Neocomian	Neocomian-Aptian
Possible correlation with Evans (1965)		J4–J5	J5	J5–K1a
PALYNOMORPHS	" Alisporites "	——	——	——
	Araucariacites australis	——	——	——
	Tsugaepollenites spp.	——	——	——
	Cyathidites spp.	——	——	——
	Baculatisporites comaumensis	——	——	——
	Contignisporites cooksonii		——	——
	Foveosporites canalis		——	——
	Ischyosporites crateris		— —	——
	Murospora florida			——
	Laevigatosporites sp.			——
	Trilites spp.			——
	Cicatricosisporites australiensis			— — —

ACKNOWLEDGEMENT

The writer wishes to thank Mr. B. E. Balme of the University of Western Australia for his continual help and for reading the manuscript.

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PALYNOLOGY OF THE OTOROWIRI SILTSTONE MEMBER, YARRAGADEE FORMATION

by B. S. Ingram

ABSTRACT

The palynomorph assemblage of the Otorowiri Siltstone Member, a new member of the Yarragadee Formation in the Mingenew—Arrino area of the Perth Basin, contains several distinct microfloras ranging in age from Devonian to Lower Cretaceous. The Lower Cretaceous forms, being the youngest, indicate the age of the rock unit ; the pre-Cretaceous elements are the result of reworking. The remanie microfossils indicate the provenance of the Otorowiri Siltstone Member and suggest, for the first time, the presence of Devonian and possibly marine Upper Jurassic sediments in the Perth Basin.

INTRODUCTION

A very distinctive palynomorph assemblage has been discovered in a siltstone from bores drilled for the Morawa town water supply in the Arrowsmith River area near Arrino, 200 miles north of Perth (Figure 17). Edgell (1963) first recorded the assemblage as 'weakly marine, Lower Cretaceous' in an unpublished palaeontological report of the Geological Survey of Western Australia on Bore 1. He recorded a similar assemblage from Mingenew P.W.D. Bore 7 (202 feet) in the following year (Edgell, 1964a). It was later found to have been recorded previously by B. E. Balme (1956) in an unpublished report on a bore near Mingenew (Mingenew 2 at 126 feet).

The same siltstone has been encountered in about half of the 26 deeper bores of the Arrowsmith River Drilling Project, including cores 8 and 9 from Bore 25, the only rotary hole. It has been found also in several Gemco holes, sited to check the band at shallow depths near a suspected outcrop. The unit is particularly helpful as the Yarragadee Formation encountered in these bores, and elsewhere in the Perth Basin, has otherwise impersistent lithologies and very slowly changing microfloral assemblages.

STRATIGRAPHY

The siltstone from which the palynomorph assemblage is derived is named the Otorowiri Siltstone Member of the Yarragadee Formation. It is lithologically distinct from the sediments above and below, and extends from Mingenew to Arrino. The name was suggested by R. Milbourne after Otorowiri Spring which is situated 7 miles east of the Arrino townsite. The type section is chosen herein in Arrowsmith River Bore 25 (29° 32′ 40″ S., 115° 32′ 10″ E.) from 830 feet to 910 feet. From this interval the only two core samples of the member were obtained. The member is 80 feet thick but it is known to be up to 120 feet thick in other bores. The lithology is predominantly siltstone and the age is Lower Cretaceous.

PALYNOMORPH ASSEMBLAGE

In addition to the distinctive lithology, the Otorowiri Siltstone Member contains an extremely interesting and diverse palynomorph assemblage. This is dominated by Lower Cretaceous microspores (within Zone C, Neocomian—Aptian, of Ingram, 1967), with rare Lower Cretaceous microplankton suggesting a slight marine influence during deposition. The remainder of the assemblage consists of older remanie spores, pollen grains, and microplankton derived from assemblages of the following ages.

a. probably Upper Jurassic
b. Middle—Upper Triassic
c. Lower Triassic
d. Upper Permian
e. Lower Permian and undifferentiated Permian
f. Devonian.

Although some of these categories are rarely represented, enough distinctive species have been found to prove their presence among the contamination. It is not unusual to find Lower Permian microspores in Lower Cretaceous sediments in the Perth Basin, but the variety and number of contaminants in the Otorowiri Siltstone Member is both remarkable and distinctive.

To illustrate the percentage of each microflora in the assemblage, counts of about 300 specimens were made from eight different samples. Two samples from each of the two available cores (from Bore 25), sludges from two intervals in Bore 18 and sludges from two other bores were used. Table 1 shows the variation between these samples.

Table 1

PERCENTAGES OF THE VARIOUS MICROFLORAS PRESENT IN THE OTOROWIRI SILTSTONE MEMBER

G.S.W.A. Arrowsmith River Bores		No. 25				No. 18		No. 19	No. 23
Samples counted	Material	Core 8		Core 9		Sludges			
	Depth (feet)	839	847	901	910	117–130	230–240	420	750–760
	Reg. No.	F6275	F6277	F6278	F6279	F6283	F6284	F6281	F6128
MICROFLORAS (excluding small 'leiospheres')		PERCENTAGES PRESENT							
Lower Cretaceous microspores		50	47	45	45	57	65	44	62
Lower Cretaceous microplankton		x	1		x		x	x	
'Upper Jurassic' microplankton			x			x	x	x	
M.-U. Triassic microspores		x	x		x		x	x	
L. Triassic microspores		4	3	2	3	9	4	6	6
'L. Triassic' microplankton		38	36	47	46	27	26	45	25
U. Permian microspores		x					x		x
Permian microspores (undifferentiated)		7	11	5	5	6	3	2	6
Devonian microspores			x		x	x	x		x
Palynomorphs in count		389	310	297	307	210	303	295	300
Ratio: counted palynomorphs / small 'leiospheres'		3/1	1/3	1/5	1/2	2/1	1/1	1/9	2/1

x = less than 1%

MICROFLORAS PRESENT IN THE ASSEMBLAGE

Following are some of the important species recognized in the various microfloras within the assemblage.

LOWER CRETACEOUS (NEOCOMIAN—APTIAN) (Plate 37: 1-7)

Microspores

Aequitriradites spinulosus (Cookson&Dettmann)
Cicatricosisporites australiensis (Cookson)
Contignisporites cooksonii (Balme)
C. glebulentus Dettmann
Dictyophyllidites crenatus Dettmann
Dictyotosporites complex Cookson & Dettmann
Ischyosporites crateris Balme
I. sp. cf. *I. punctatus* Cookson & Dettmann
Laevigatosporites sp. nov.
Matonisporites crassiangulatus (Balme)
M. sp. cf. *M. phlebopteroides* Couper
Murospora florida (Balme)
Pilosisporites ?notensis Cookson & Dettmann
Trilobosporites pulverulentus (Verbitskaya)
T. sp. cf. *T. tribotrys* Dettmann
—and many other species.

This is a somewhat unusual assemblage for Western Australia containing many forms common in eastern Australian sediments. Although it bears some of the characters of Dettmann's (1963) Speciosus Assemblage it is as yet not known how accurately her palynological zones can be correlated with the microfloral sequence in Western Australia. Also the presence of common *Murospora florida* with several species of *Trilobosporites* and *Pilosisporites* is not consistent with her evidence in Eastern Australia. This may be explained by the youngest microflora being of Aptian age with Neocomian contamination. Until the ranges of these species are known in detail in the Perth Basin, the age of this microflora is best considered as Neocomian—Aptian.

Microplankton

Rare and poorly preserved specimens of *Pterospermopsis australiensis* Deflandre & Cookson (identified by Edgell, 1964b), *Baltisphaeridium hirsutum* (Ehrenberg), and indeterminate species of *Gonyaulax* and *Canningia* are present. These are considered to be of Lower Cretaceous age.

UPPER JURASSIC MICROPLANKTON (Plate 37: 8, 9)

Dingodinium jurassicum Cookson & Eisenack and *Wanea clathrata* Cookson & Eisenack have been identified. Evans (pers. comm. 1966) considers *D. jurassicum* to be restricted to early Upper Jurassic at least in Northern Australia and New Guinea. Cookson & Eisenack (1958, p. 58) similarly restrict *W. clathrata* in a study which included some Carnarvon Basin samples. The two forms are commonly found together in the Dingo Claystone, Carnarvon Basin which is no younger than Lower or Middle Kimmeridgian. However, the possibility that these forms existed in the Perth Basin in the Lower Cretaceous cannot be dismissed.

MIDDLE—UPPER TRIASSIC MICROSPORES (Plate 37: 10, 11)

Two species of spores, recorded only from Middle—Upper triassic strata in Australia have been identified, i.e. *Guthoerlisporites cancellosus* Playford & Dettmann and *Polycingulatisporites crenulatus* Playford & Dettmann.

LOWER TRIASSIC MICROSPORES AND MICROPLANKTON (Plate 37: 12–16)

Many microspores species recorded by Balme (1963) from the Kockatea Shale are present. These include:

Krauselisporites cuspidus Balme
Densoisporites playfordi (Balme)
Lundbladispora willmotti Balme
Osmundacidites senectus Balme
Taenisporites ?noviaulensis Leschik

Abundant specimens of small microplankton of the genera *Veryhachium* (?*Wilsonastrum*), *Micrystridium*, and *Leiosphaeridia* are also present. Although these are long-ranging forms, Balme (1963) records that, in Kockatea Shale samples, ratios of spores to microplankton similar to the above forms are as high as 1 to 65. Therefore, although a few are probably of Lower Cretaceous age, for the purpose of the counts all such microplankton were considered Lower Triassic. Separated from these were smaller (10-15μ) leiospheres (or ?*Spheripollenites* of Jansonius, 1962) which due to their abundance and unknown age (although most likely Lower Triassic), were only estimated as a proportion of other grains counted.

UPPER PERMIAN MICROSPORES (Plate 37: 17,18)

Among the many Permian grains recorded, at least four species are most common in the Upper Permian although they may be found occasionally in the late Lower Permian. These are *Dulhuntispora dulhuntyi* Potonié, *D. parvithola* (Balme & Hennelly), *Acanthotriletes villosus* Balme & Hennelly and *Marsupipollenites sinuosus* Balme & Hennelly.

LOWER PERMIAN AND UNDIFFERENTIATED PERMIAN MICROSPORES (Plate 37 : 19, 20, 21)

As previously stated Lower Permian microspores are often common contaminants within Lower Cretaceous strata in the Perth Basin. Many undifferentiated Permian forms were included in this microflora, due to the relative abundance of Lower Permian compared to Upper Permian strata in the Perth Basin. *Nuskoisporites*, *Krauselisporites*, and '*Striatites*' are some of the common Permian forms in the Otorowiri Siltstone Member.

DEVONIAN MICROSPORES (Plate 37 : 22, 23)

Rare grains identified as *Emphanisporites* sp. and *Leiozonotriletes carnarvonensis* Balme are definitely of Devonian age. They are only known in Western Australia from the Gneudna Formation of the Carnarvon Basin (Balme, 1960). More common grains, assigned to *Punctatisporites* and ?*Geminospora* are tentatively considered to be Devonian.

GEOGRAPHICAL EXTENT

The Otorowiri Siltstone Member is known from a narrow linear belt, west of and adjacent to the Urella Fault extending from Mingenew 2 Bore in the north to G.S.W.A. Arrowsmith River 25 Bore in the south (Figure 17). In the Arrowsmith River area it occurs at 0 to 200 feet above sea level in bores in a graben 3 to 4 miles wide (containing Bores 11, 16, 13 etc.). To the west it possibly crops out on the adjoining horst, occurring in bores at 500 to 700 feet above sea level. The suspected outcrop was examined for its microflora but only Quaternary spores and pollen grains were obtained. Shallow Gemco holes nearby, sited stratigraphically higher, intersected siltstones at the same level as the outcrop. These siltstones contained microfloral assemblages typical of the Otorowiri Siltstone Member. The outcrop may thus be the member, with all the original assemblage oxidized and now replaced by recent contaminants trapped in the exposed mud, or it may be a fortuitously sited Quaternary deposit.

STRATIGRAPHICAL SIGNIFICANCE

The main use of the Otorowiri Siltstone Member is as a stratigraphic marker in the sediments drilled in the Arrowsmith River area which consist of impersistent sand and silt of the Yarragadee Formation. The member is considered to have a distinctive lithology, and after correlations have been made on palynological grounds, the evidence suggests that there is only one siltstone unit.

Confirmatory evidence for the usefulness of the member as a stratigraphic marker was provided from seismic work. A fault with a downthrow of 500 feet to the east, roughly parallel to the Urella Fault and running just west of the position of Bore 6, had been postulated from palynological evidence. A seismic line across the area located a fault in a similar position with an estimated downthrow of 600 feet to the east.

AGE OF THE MEMBER

With the great extent of geological time represented by the various microfloras recognized within the assemblage, the actual age of the rock unit must be that of the youngest microflora. This cannot be defined more closely than Neocomian—Aptian for the reasons given above.

ORIGIN OF THE MEMBER

Sedimentation of the Otorowiri Siltstone Member is considered to have been initiated by a sudden movement on the Urella Fault (or an associated fault) in the Lower Cretaceous. The evidence of the slight marine influence during deposition could indicate a basin downward movement, rather than eastern basement upwards, causing a brief marine incursion. However, the major result was rapid erosion (presumably to the east), exposing fresh, older sediments. These were swept into the basin before the palynomorphs they contained could be oxidized, as would be the case under slower conditions of erosion.

The assemblage thus formed gives an indication of the various strata cropping out to the east during Lower Cretaceous times. The excellent preservation of many of the remanie grains suggests they were not transported very far ; actual distances are of course impossible to ascertain. The problem of the provenance of the various microfloras will now be considered, with the more easily accounted for being discussed first.

A Lower Permian source is easy to envisage. Edgell (1965) described a marine fauna of this age from an outcrop on the eastern margin of the Arrowsmith River area near Bore 5. Lower Permian palynomorph assemblages have also been found in Bores 7 and 15, one of Sakmarian age and the other of Artinskian age. Thus a ready source of Lower Permian palynomorphs is still available, and in fact they were still being reworked into Quaternary strata. The Permian sediments west of the Urella Fault also illustrate the complexity of the zone associated with this fault. It apparently has many thin fault blocks of various ages along its length, and these blocks are considered the most likely source of most of the contamination.

This source for the remanie grains can be further illustrated by the unexpected occurrence of Kockatea Shale at 80 feet in U.W.A. Bore 10 (Balme, pers, comm. 1966), drilled near Mingenew in 1965 by the Department of Geology, University of Western Australia. This, or a similar occurrence could be the source of the Lower Triassic grains although the closest known present day outcrop is in Kockatea Gully about 40 miles north of Mingenew.

The closest known Upper Permian outcrop is the Wagina Sandstone in the Woolaga Creek area, about 12 miles east of Mingenew. Middle—Upper Triassic strata of the Perth Basin (Lesueur Sandstone and Woodada Formation) have at present only one known 'possible outcrop' (Willmott, 1964)—in the Cockleshell Gully area, 60-70 miles southwest of Arrino. However, these two microfloras may also have been derived from fault blocks now either completely eroded, too deeply weathered to be recognized, or covered by Quaternary sands.

It is more difficult to account for the origin of the Upper Jurassic and Devonian palynomorphs. If the Upper Jurassic microplankton are in fact of this age (see above) then their source is not known. Drilling in many bores in the Yarragadee Formation in the Perth Basin has not as yet shown any marine strata in the lower (Upper Jurassic) parts of the formation.

Devonian strata also are not known from the Perth Basin, the nearest rocks of this age being in the Carnarvon Basin. In fact the most southerly known occurrence is in the Pelican Hill Bore north of Carnarvon, about 350 miles north of Mingenew (see Balme, 1960). It is considered unlikely that the Devonian grains found in the Otorowiri Siltstone Member have been transported this far and therefore it is suggested that Devonian strata are (or were) present in the Perth Basin—or on the shield to the east.

CONCLUSIONS

1. The Otorowiri Siltstone Member is a distinct stratigraphic unit of the Yarragadee Formation in the Arrino—Mingenew area.

2. It contains a distinct palynomorph assemblage with grains present ranging in age from Devonian to Lower Cretaceous.

3. The youngest microflora (Lower Cretaceous) denotes the age of the member.

4. The older remanie grains indicate sediments of the ages represented were cropping out in the area in the Lower Cretaceous.

5. Unoxidized portions of these sediments were deposited in the basin, probably after a sudden movement on the Urella Fault caused rapid erosion of the older fault blocks.

6. Devonian and possible marine Upper Jurassic palynomorphs are recorded from the Perth Basin for the first time.

ACKNOWLEDGEMENT

The writer wishes to thank Mr. B. E. Balme of the University of Western Australia for his continual help and for reading the manuscript.

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PLATE 37

Magnification of all photomicrographs x 500

Lower Cretaceous (1-7)

1. *Matonisporites* sp. — F 6284/5
2. *Trilobosporites* sp. — F 6284/4
3. *Klukisporites* sp. cf. *K. scaberis* (Cookson & Dettmann) — F 6128/8
4. *Pilosisporites* sp. cf. *P. notensis* Cookson & Dettmann — F 6284/3
5. *Contignisporites* sp. — F 6128/5
6. *Cicatricosisporites australiensis* (Cookson) — F 6128/10
7. *Laevigatosporites* sp. — F 6128/7

Upper Jurassic (8 & 9)

8. *Dingodinium jurassicum* Cookson & Eisenack — F 6284/6
9. *Wanea clathrata* Cookson & Eisenack — F 6284/6

Middle—Upper Triassic (10 & 11)

10. *Guthoerlisporites cancellosus* Playford & Dettmann — F 6282/5
11. *Polycingulatisporites crenulatus* Playford & Dettmann — F 6282/14

Lower Triassic (12-16)

12. *Osmundacidites senectus* Balme — F 6282/6
13. *Lundbladispora willmotti* Balme — F 6128/4
14. *Krauselisporites cuspidus* Balme — F 6281/4
15. *Taenisporites* sp. cf. *T. noviaulensis* Leschik — F 6128/19
16. *Veryhachium* sp. — F 6281/12

Upper Permian (17 & 18)

17. *Dulhuntispora parvithola* (Balme & Hennelly) — F 6281/1 (31·9 x 94·6)*
18. *Marsupipollenites sinuosus* Balme & Hennelly — F 6282/10

Lower Permian (19-21)

19. *Vittatina* sp. — F 6128/11
20. "*Striatites*" sp. — F 6275/1
21. *Krauselisporites* sp. — F 6284/7

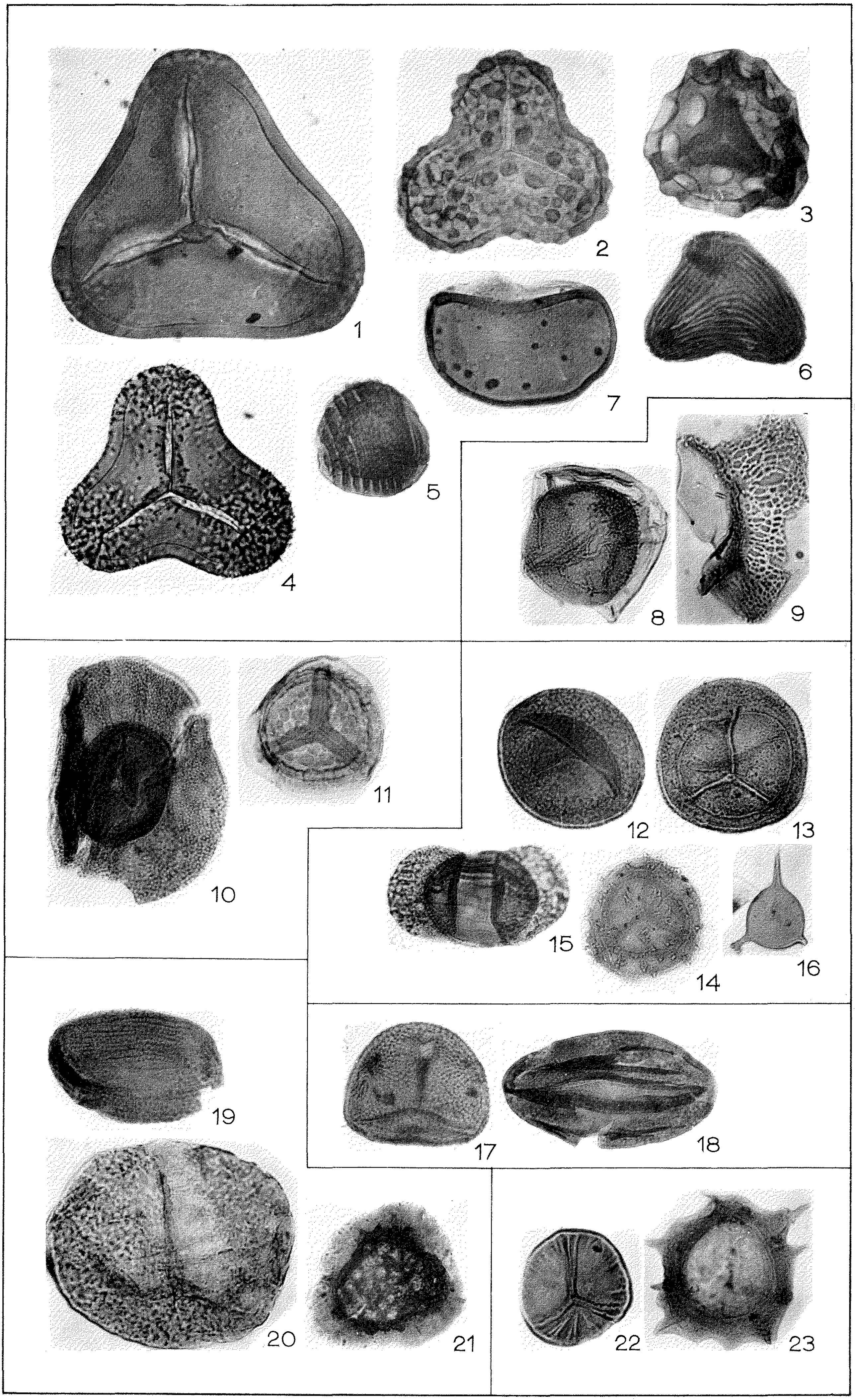
Devonian (22 & 23)

22. *Emphanisporites* sp. — F 6284/9
23. *Spinozonotriletes carnarvonensis* Balme — F 6284/10

* Coordinates on Leitz Ortholux microscope 587962

All other slides are single grain mounts

PLATE 37



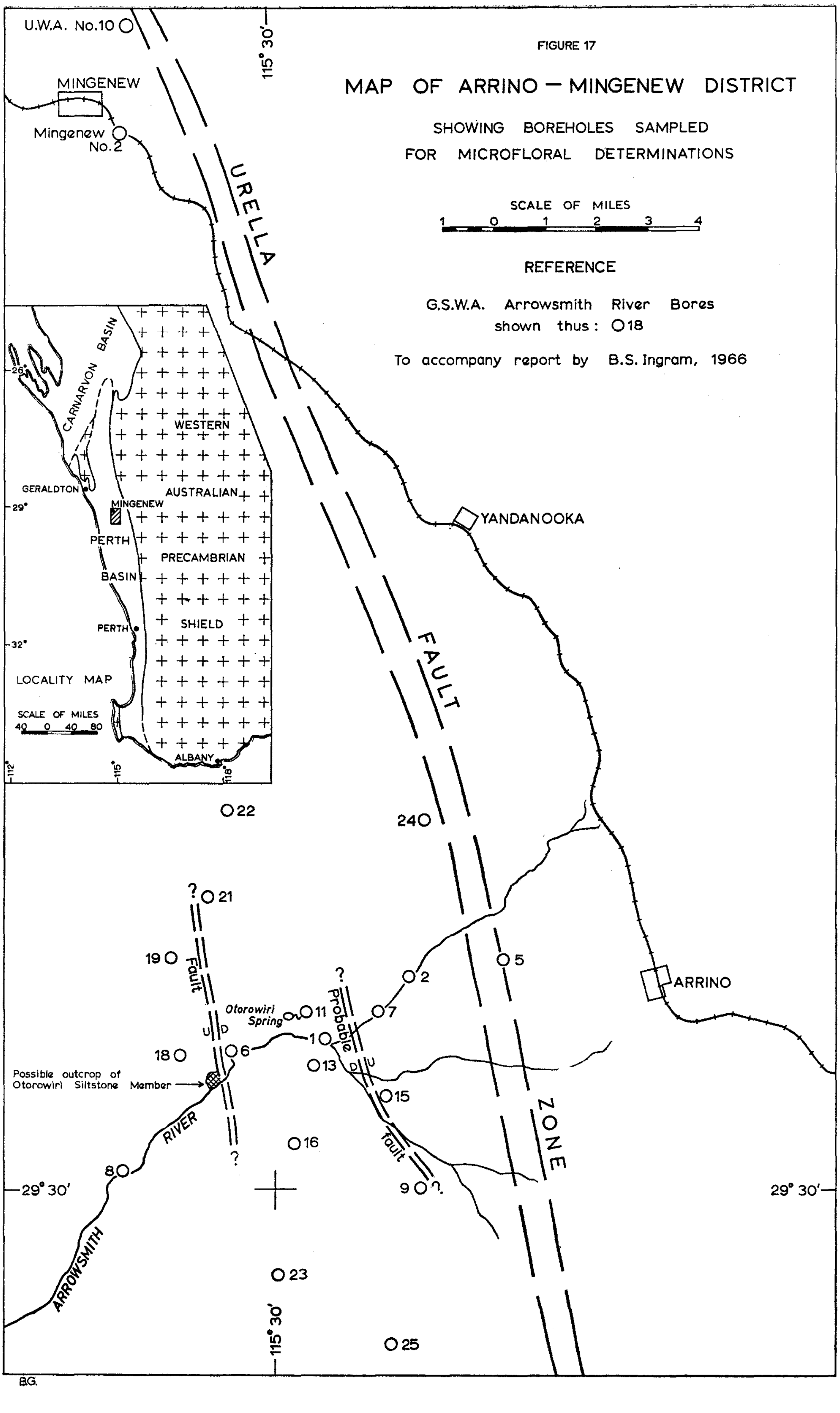


FIGURE 17
MAP OF ARRINO — MINGENEW DISTRICT
SHOWING BOREHOLES SAMPLED
FOR MICROFLORAL DETERMINATIONS
SCALE OF MILES
1 0 1 2 3 4
REFERENCE
G.S.W.A. Arrowsmith River Bores
shown thus : O18
To accompany report by B.S. Ingram, 1966
U.W.A. No.10
MINGENEW
Mingenew No.2
URELLA
FAULT
ZONE
YANDANOOKA
ARRINO
115° 30'
29° 30'
Otorowiri Spring
Fault
Probable Fault
U D
Possible outcrop of Otorowiri Siltstone Member
RIVER
ARROWSMITH
1
2
5
6
7
8
9
11
13
15
16
18
19
21
22
23
24
25
CARNARVON BASIN
WESTERN AUSTRALIAN PRECAMBRIAN SHIELD
GERALDTON
MINGENEW
PERTH BASIN
PERTH
ALBANY
LOCALITY MAP
SCALE OF MILES
40 0 40 80
26°
29°
32°
112°
115°
118°
B.G.

INDEX

DIVISION V

School of Mines, Western Australia Annual Report — 1966

The Under Secretary for Mines.

I have the honour to submit for the information of the Honourable the Minister for Mines my report for 1966. The report refers to Kalgoorlie and to Norseman.

KALGOORLIE.

Enrolments.

The number of students enrolled in 1966 was 240—a decrease of 35 by comparison with the previous year. The quality of the intake was poor and neither the industry nor the School attracted any number of competent young men. This was indeed unfortunate, particularly in view of the great expansion taking place in the mineral industry.

Table I gives the individual and class enrolments for 1966 and for the four previous years; Table II, the enrolments in the various subjects; and Table III, the enrolments in the various courses.

Table III shows that over the five years 1962/66 the greatest loss has been in students enrolled for "No set Course" and the next greatest in students enrolled for Associateship Courses. The apparent gain in students enrolled for Certificate Courses is not significant because the number enrolled in 1962 appears low by comparison with subsequent years and also the increase is very small. The loss in students enrolled for "No set Course" is more important than it appears because the greatest loss appears to have taken place in the groups from which "Course" students might have come later.

Revenue.

The revenue for the year was $12,421. Table IV shows how the revenue was made up; and Table V, the fees paid by students in the various age groups. The money received include $4,000 paid into the Apparatus and Equipment Trust Fund. As would be expected the revenue decreased by comparison with 1965.

Staff.

The following staff changes occurred during the year:

- Bartram, P. M.; Library Assistant; 10/6/66—Resigned.
- Hill, P.; Typist; 13/6/66—Appointed.
- Brown, L. M.; Typist; 1/2/66—Appointed.
- Stephens, K. E.; Typist; 10/1/66—Appointed.
- Cruickshank, H. J.; Typist; 18/7/66—Appointed.
- Campbell, D. A.; Messenger; 24/2/66—Appointed.
- Blackwell, A. J.; Lecturer; 18/4/66—Appointed.
- Mason, R. C.; Lecturer; 14/2/66—Appointed.
- Willis, L. G.; Cadet; 28/2/66—Appointed.
- Ostwald, J.; Lecturer; 27/5/66—Resigned.
- Brandt, R. T.; Senior Lecturer; 30/8/66—Appointed.
- Burns, A. R.; Lecturer; 3/1/66—Appointed.
- Foxton, A. J.; Laboratory assistant; 5/1/66—Appointed.
- Moriarty, M. E.; Laboratory Assistant; 18/4/66—Transferred to Geology Department.
- Lethlean, W. R.; Laboratory Assistant; 21/3/66—Appointed.
- Seifken, T. C.; Laboratory Assistant; 5/9/66—Appointed.

Courses of Study.

No changes were made in the Courses offered for study in 1966, but during the year all Courses were reviewed and changes will be made in 1967.

About mid-year the Advisory Committee appointed four sub-committees to consider School of Mines Courses—mining, metallurgy, engineering, and geology sub-committees were appointed. Invitations to join these sub-committees were issued to members of the Advisory Committee, to members of the School Staff, and to representatives of industry, including industry outside Kalgoorlie and, indeed, outside Western Australia. Each of these sub-committees met a number of times and by the end of the year the general pattern of the future Courses had been set, but all details had not been decided. The sub-committees met as follows:

Sub Committee	Number of Meetings	Average Number Members Present
Mining	3	7/8
Metallurgy	4	6/8
Engineering	3	5/7
Geology	4	5/6

Towards the end of the year the recommendations of the sub-committees were considered at a meeting of the Advisory Committee and at a meeting of the Director and Heads of Departments. In 1967 the following Courses are to be available:

Pre 1967 Courses.

- Associateship—Second, third, and fourth years.
- Certificate—All years, but new students to enrol in the 1967 Courses.
- Technician—All years.

1967 Courses.

- Associateship—First year only.
- Four/five year Certificate—All years, but subject to revision.
- Three Year Certificate—This is a new type of course. Most subjects available.

With the exception of the Three-Year Certificate Courses, the proposed Courses for 1967 follow the same pattern as the previous Courses. Details are as follows:

Associateship Courses:

Mining, Metallurgy, Engineering, Mining Geology—Entrance level Leaving. Require two years of full-time study followed by two years of part-time.

Certificate Courses (Four/Five-Year):

Mine Surveyor, Chemical Technician (replacing Assayer's Certificate), Engineering Draughtsman—Entrance level Junior. Four to five years of part-time study.

Certificate Courses (Three-Year):

Student to select subjects from given groups of subjects.—Entrance level Junior. Three years of part-time study.

Complete information about the new Courses will be published in the 1967 Prospectus.

Annual and Supplementary Examinations.

The results of the Annual Examinations are summarized in Tables VI and VII, which are based on class enrolments and on individual enrolments respectively. The figures are generally similar to those of previous years, but the percentage sitting for annual examinations (Table VI) is lower than that of the four previous years. On the other hand the percentage passing is higher.

The results for individual subjects are given in Appendix 1.

Scholarships and Prizes

Most scholarship holders completed a satisfactory year's work and none a bad year's work. Two were recommended for part-time study in 1967 and one was told that his attendance was not completely satisfactory for a scholarship holder.

Two students—D. G. Brioschi and T. E. Brooks—held Mines Department Senior Scholarships and each completed a satisfactory year's work.

Nine students held Chamber of Mines Scholarships. Three students—B. L. McRostie, D. J. Sands, D, J. Head,—completed Associateship Courses. Since this scholarship scheme was commenced in 1953, twenty-three holders of scholarships have completed Associateship Courses. Of the 23 students concerned, 8 are in Western Australia and four are associated with gold-mining.

One student—D. A. Faulkner—held a Repatriation Department Scholarship and he completed the Associateship Course in Metallurgy.

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

There was some delay in the award of A.E.I. Overseas Fellowships, but M. L. Woolhouse, who completed the Associateship Course in Engineering in 1966, was awarded one of these Fellowships early in 1967 and will leave for England in mid-1967.

Diplomas and Certificates.

Table VIII shows that 16 students completed Associateship Courses in 1966; 12, Certificate Courses; and 6, Technician Courses.

As 1966 was Technical Training Year a combined official opening of Technical Training Year on the Goldfields and Presentation Night was held in the Kalgoorlie Town Hall on Wednesday, June 1. Presentations of awards and prizes to students of the School of Mines, to students of the Eastern Goldfields Technical School, and to students of the Kalgoorlie Regional Hospital Training School for Nurses were made by the Acting Minister for Mines and Minister for Works and Water Supply, the Honourable Ross Hutchinson, D.F.C., M.L.A., who also officially opened Technical Training Year on the Goldfields. The Deputy Chairman of the Central Committee, Mr. W. J. Paterson, and three members of the Committee were present at the function, which was addressed by Mr. Paterson and by Mr. Elvey, President of the Chamber of Mines. After the Presentations and a vote of thanks proposed by Mr. B. M. Phillips, President of the School of Mines Students' Association, the Technical Training Year film "Training for Development" was shown.

Library.

The library has continued to serve both students and the mining industry on the Goldfields and throughout the State. The reading room is used regularly by students, although not as much as could be. There is a continued increase in requests for material from mining companies—which is probably due to prompt circulation of our library bulletins. Unsolicited appreciation of the bulletin has been received by the library.

We have been fortunate in having a full-time typist all the year, but the sorting of material from the Engineering Department, which was moved at the end of 1965 has made a lot of extra work, and little back work has been done.

The number of items catalogued at December 1966 was 10,230, the new titles for that year being 698—approximately the same as the previous year. There is, however, still a quantity of old material which has not been catalogued.

There has been a further increase in inter-library loans and use of the library by mining companies outside of the Kalgoorlie district. Sixty-eight items were requested on interlibrary loan, and these were met with the exception of 11 items which could not be supplied from our stock. The School borrowed a total of 27 items. Subject indexing has been kept up to date and 555 selected items on mining and metallurgical practice were included in the library bulletins.

The library photocopy service has been used consistently throughout the year.

Services to the Public.

The School continued to provide the usual services to industry and to the public in addition to its teaching activities. The number of samples submitted for assay or for mineral determination increased very considerably—from 442 in 1965 to 1183 in 1966. The greatest increase was in samples for "assay—other than gold". These increased from 54 in 1965 to 553 in 1966 and, as might be expected, most of these samples were submitted for nickel assay. The next greatest increase was in specimens submitted for mineral determination—from 136 to 356. These figures do not include samples submitted to the Metallurgical Laboratory for pay assay.

Commonwealth Advisory Committee on Advanced Education.

Early in the year a Submission was prepared for the Commonwealth Advisory Committee and went forward with the State Submission. The Commonwealth Committee consists of the following:

Dr. I. W. Wark (Chairman).
Mr. V. G. Burley.
Professor Gordon Greenwood.
Mr. S. E. Huddleston.
Mr. J. H. Kaye.
Professor G. L. McClymont.
Mr. H. P. Weber.
Dr. H. S. Williams.

The Submission referred to the triennium 1967-1969 and covered both recurrent and capital expenditure.

The Committee issued its First Report in June 1966 and most of the Committee's recommendations were accepted by the Commonwealth Government in September, 1966. In October, 1966 the decisions of the Commonwealth Government were embodied in the States Grants (Advanced Education) Act 1966 (Number 89 of 1966).

Subject to the conditions set down in the Act the following grants were made to the School of Mines:

Recurrent Expenditure — Maximum Grant

	$
1967	19,810
1968	28,410
1969	31,730

Capital Expenditure.

	$
Completion of mining and engineering building	145,000
Alterations and additions to main building	63,000
Equipment	112,500

Buildings.

Stage IA of the building for Mining and for Engineering was commenced early in 1966 and work was still in progress at the close of the year. Further consideration was given to Stage IB of this building and also to Stage III of the building programme. Stage IB has been so designed that it can be joined to Stage III, which will house the metallurgy section of the School.

Requirements of the School.

These remain as set down in the 1965 Annual Report.

Advisory Committee.

The Advisory Committee has met eight times and members have given a lot of time to the affairs of the School. Members of the Committee have taken part in the discussions on the revision of Courses and in addition have also considered various matters related to submissions to Commonwealth and State Committees.

During the year the Committee approved of the purchase of a McPhar Rope Testing Machine at a cost of $7675. This machine was purchased after consultations with Dr. Symes (N.S.W.) and is the only one of its kind in Australia.

In December Mr. Golding, who was leaving Kalgoorlie, relinquished his position on the Committee as the representative of the Society of Associates. He had been a member of the Committee since 1959 and the Committee recorded its appreciation of his services.

Kalgoorlie Metallurgical Laboratory.

During the year four requests for investigations were received and two investigations were completed. One of the completed investigations referred to tin ore and the other to copper ore. The Senior Research Metallurgist continued as a member of the Chamber of Mines Metallurgical Committee and continued to help mine owners and prospectors with metallurgical advice. The year's work is summarized in Table X and more details are given in Appendix 3.

Students' Association.

The President of the Students' Association was Mr. B. M. Phillips, who completed the Associateship Course in Mining at the end of the year and returned to Tasmania. The Association was active during the year and the usual functions were held. Just prior to the Ball, the Association produced a news sheet which was very successful and large numbers were sold. The profit from the Ball was as is usual, given to the Slow Learners Group in Boulder. Our congratulations and best wishes go to those students who were successful at the Annual Examinations and particularly to those who completed Courses.

Technical Training Year, 1966.

In May, 1965, Dr. H. S. Williams, Chairman of the Central Committee for Technical Training Year, called a preliminary meeting of a small number of people likely to be interested in Technical Training Year in Kalgoorlie/Boulder. Those present agreed that a second larger meeting should be called to form a Local Area Committee. The second meeting was held on June 30, Mr. R. A. Hobson, Director of the School of Mines was elected Chairman and a Local Area Committee of some 40 persons was formed. Smaller sub-committees were also formed and were active throughout the year.

All available means of publicity were used to bring the need for training and information about the facilities available to the notice of the people of Kalgoorlie and Boulder—particularly to the young people. Talks, displays, radio interviews, newspaper articles, films, excursions, careers, conferences were all used. Every endeavour was made to give information on as wide a range of subjects as possible, but some emphasis was given to the mineral industry, which urgently needs trained men at all levels.

The Year was officially opened on the Goldfields by the Honourable Ross Hutchinson, Minister for Works and Water Supply and Acting Minister for Mines at a function in the Kalgoorlie Town Hall on June 1, 1966. Reference has already been made to this function earlier in this report.

During August fifteen Pioctet delegates made a brief two day visit to Kalgoorlie and were shown various points of interest in the district. Three delegates, one from Great Britain, one from India, and one from Kenya, took part in a School of the Air lesson and were able to talk to children in localities up to 300 miles from Kalgoorlie.

Committee on Tertiary Education in Western Australia.

This Committee, with Sir Lawrence Jackson as Chairman, was appointed in August, 1966 to inquire into tertiary education in Wes ern Australia. Shortly after the Committee's appointment the Chairman paid a brief visit to the School. Towards the end of the year preparations were made to submit information about the School to the Committee early in 1967.

NORSEMAN.

Enrolments.

The number of students enrolled was 51—an increase of one by comparison with the previous year. Table I sets out the individual and class enrolments during the year and for the four previous years; Table II, the enrolments in the various classes; and Table III, the enrolments in the various Courses.

Revenue.

The revenue was $486, mainly from class fees.

Staff.

There were no changes in the full-time staff. Eight part-time instructors were employed. Seventeen subjects were taught.

Examinations.

The results of the Annual and Supplementary Examinations are summarized in Tables VI and VII—Table VI is based on class enrolments and Table VII on individual enrolments. The results are satisfactory and similar to those of earlier years.

The results for individual subjects are given in Appendix 1.

Scholarships and Prizes.

The Reg Dowson Scholarships for 1966 were awarded to J. R. Fleay and R. J. Horan. The two students who were awarded these Scholarships in 1965 each completed a fair year's work. No other awards were made to Norseman students.

Buildings.

Generally the buildings are in satisfactory condition. The class rooms were painted internally during the year.

Advisory Committee.

The Advisory Committee did not meet during 1966.

ACKNOWLEDGEMENTS.

The assistance and co-operation of all members of the Staff, both full-time and part-time, is gratefully acknowledged. The statistical information contained in this Report has been compiled by the Registrar and the office staff in Kalgoorlie and by the Registrar in Norseman. Assistance and co-operation throughout the year received from Advisory Committees, Kalgoorlie and Norseman, staffs of Mining Companies, Mines Department Staff and others is also gratefully acknowledged. Special mention must be made of the Advisory Committee in Kalgoorlie and of the various sub-committees formed to consider School of Mines Courses.

May 18, 1967.

R. A. HOBSON,
Director, School of Mines.

TABLE I.

ENROLMENTS.

1962-1966.

Year	Kalgoorlie		Norseman	
	Individual	Class	Individual	Class
1962	352	945	69	160
1963	365	926	68	140
1964	329	830	59	128
1965	275	858	50	122
1966	240	775	51	122

TABLE II.

CLASS ENROLMENTS.

1966

Subject	Kalgoorlie	Norseman
Chemistry P	33	11
Chemistry Q	10	....
Chemistry 1	10	....
Chemistry 2	5	....
Analytical Chemistry 1	5	....
Analytical Chemistry 2	4	....
Chemical Metallurgy 1	4	....
Chemical Metallurgy 2	8	....
Mineral Dressing 1	9	....
Mineral Dressing 2	3	....
Mineral Dressing 3	2	....
Physical Metallurgy	7	....
Assaying	6	....
Metallurgy A	1	12
Mathematics PA	34	10
Mathematics PB	34	....
Mathematics QA....	38	8
Mathematics QB....	28	5
Mathematics 1.1	23	....
Mathematics 1.2	28	....
Mathematics 1.2 (Stat.)	5	....
Mathematics 2	6	....
Physics Q....	20	8
Physics 1.1	22	....
Physics 1.2	20	....
Physics 2	6	....
Electronics	6	....
Engineering Drawing P	29	7
Engineering Drawing Q	24	12
Engineering Drawing 1	18	....

TABLE II.—continued.

CLASS ENROLMENTS—continued.

1966

Subject	Kalgoorlie	Norseman
Engineering Drawing W	4	4
Engineering Design	4	....
Mechanical Engineering 1	17	....
Mechanical Engineering 2	8	....
Electrical Engineering 1	15	....
Electrical Engineering 2.1	3	....
Electrical Engineering 2.2	5	....
Structural Engineering 1	11	....
Structural Engineering 2.1	6	....
Structural Engineering 2.2	6	....
Machine Design 1.1	6	....
Machine Design 1.2	4	....
Hydraulics	10	....
Materials of Construction	8	....
Workshop Practice 1	6	....
Workshop Practice A	....	....
Workshop Practice B	....	5
Workshop Practice C	....	6
Workshop Practice D	....	....
Steam Engine Driving	....	....
Welding A	27	10
Welding B	7	....
Internal Combustion Engines	10	....
Geology Q	25	....
Geology 1.1	19	....
Geology 1.2	12	2
Geology 2.1	6	....
Geology 2.2	8	....
Geology 2.3	3	....
Geology 3.2	....	....
Geology 3.3	....	....
Mining 1	5	10
Mining 2.1	7	....
Mining 2.2	5	....
Mining 3	6	....
Mining 3 (Sect. B)	....	....
Mine Ventilation....	3	....
Surveying 1	13	....
Surveying 2.1	4	....
Surveying 2.2	6	2
Mining A	5	....
Mining B	....	....
English P	16	....
English Q....	13	....
English 1	15	....
Leaving English	....	....
Mathematics A	....	....
Mathematics B	....	....
Physics P	....	....
Electrical Theory A	....	....
Electrical Theory B	....	4
Electrical Theory C	....	....
Electrical Drawing A	....	6
Totals	775	122
Totals, 1965....	858	121

TABLE III.

NUMBER OF STUDENTS ENROLLED FOR VARIOUS COURSES.

Course	Kalgoorlie					Norseman				
	1962	1963	1964	1965	1966	1962	1963	1964	1965	1966
ASSOCIATESHIP COURSES										
Mining	27	34	31	19	21	6	4	3	1	....
Metallurgy	15	18	20	19	19	....	....	....	....	....
Engineering	44	37	43	31	25	3	....	....	....	....
Mining Geology	11	9	7	7	8	....	....	....	....	....
Total	97	98	101	76	73	9	4	3	1	....
CERTIFICATE COURSES										
Assayer's	6	10	8	4	3	....	....	....	....	....
Mine Surveyor's	27	37	27	30	25	11	9	9	10	11
Mine Manager's	3	....	....	....	....	....	....	....	....	....
Engineering Draughtsman's	8	33	29	24	18	....	8	....	3	....
Electrical Engineering....	....	....	....	....	....	1	....	....	....	....
Mechanical Engineering	1	....	....	....	....	....	....	....	....	....
Total	45	80	64	58	46	12	17	9	13	11
TECHNICIAN COURSES										
Engine Operation and Maintenance	1	....	....	....	....	12	2	....	....	....
Workshop Foreman's	2	....	....	....	....	6	....	....	....	....
Welding	24	17	19	11	14	6	7	6	4	6
Workshop (Mechanical)	....	....	1	....	1	....	12	1	20	12
Workshop (Electrical)	....	2	....	....	....	....	5	....	5	6
Mine Manager's (2nd class)	....	5	8	7	5	....	....	1	2	2
Total	27	24	28	18	20	24	26	8	31	26
NO SET COURSE										
Preparatory subjects	38	27	17	26	29	11	11	....	3	7
Qualifying subjects	22	17	17	16	7	....	....	....	....	3
External students	....	....	2	....	....	....	....	....	....	....
Junior and Leaving	28	32	18	7	1	....	....	....	....	....
University	3	1	1	2	....	....	....	....	....	....
Others	92	86	81	72	64	12	10	39	2	4
Total	183	163	136	123	101	23	21	39	5	14
TOTAL FOR YEAR	352	365	329	275	240	68	68	59	50	51

TABLE IV

REVENUE—1964-1966.

	Kalgoorlie			Norseman		
	1964	1965	1966	1964	1965	1966
	$	$	$	$	$	$
Class Fees	3,460·55	3,003·25	2,532·05	414·05	371·20	447·20
Lecture Notes	120·75	103·00	85·50	18·25	16·00	16·75
Laboratory Deposits	220·00	188·00	182·00	16·00	....	20·00
Supplementary Examinations	100·00	72·00	46·00	8·00	....	2·00
Apparatus and Equipment Trust Fund	....	4,000·00	4,000·00	....	....	....
Metallurgical Laboratory Trust Fund	1,881·70	1,005·55	1,835·55	....	....	....
Commonwealth Grants—Research Laboratory—Trust Fund	5,703·00	6,060·00	3,060·00	....	....	....
Students' Association	437·50	373·50	320·50	....	....	....
Mine Managers and Underground Supervisors	107·10	105·05	86·10	....	....	....
Sundries	363·92	185·48	273·10	....	....	....
Total	$12,394·52	$15,095·83	$12,420·80	$456·30	$387·20	$485·95

TABLE V

NUMBERS OF STUDENTS PAYING FEES.
1964-1966.

Group No.	Description	Kalgoorlie						Norseman					
		1964	1965	1966				1964	1965	1966			
		Total	Total	Full Time	Part Time	External	Total	Total	Total	Full Time	Part Time	External	Total
1	Students under 18. Class fees, deposits, lecture notes fee, Students' Association	86	77	6	57	....	63	24	16	....	17	....	17
2	Students 18-20. Class fees and other fees as for Group 1	76	58	14	51	....	65	19	18	....	15	....	15
3	Students 21 and over. Class fees and other fees as for Group 1	147	107	10	85	....	95	14	15	....	19	....	19
4	Returned Servicemen. Exempt Class fees	9	9	....	2	....	2	1	....	....	....	....	....
5	Staff. Exempt class fees	9	22	....	13	....	13	1	1	....	....	....	....
6	Scholarship Holders. Exempt class fees	2	2	2	....	....	2	....	....	....	....	....	....
		329	275	....	....	....	240	59	50	....	....	....	51

TABLE VI

RESULTS OF ANNUAL AND OF SUPPLEMENTARY EXAMINATIONS BASED ON CLASS ENROLMENTS, 1962-1966.

	Kalgoorlie					Norseman				
	1962	1963	1964	1965	1966	1962	1963	1964	1965	1966
Class Enrolments = A	945	931	827	858	775	160	140	115	122	122
Number of entries for Annual Examinations = B	609	633	581	558	426	118	96	97	82	92
B/A per cent.	64	68	70	65	55	74	69	84	67	75
Number of passes at Annual Examinations as a per cent. of A	49	49	53	53	51	51	54	75	55	60
Number of passes at Annual Examinations as a per cent. of B	75	71	75	81	93	69	79	89	82	79
Number of passes at Annual Examinations and Supplementary Examinations as a per cent. of A	52	52	57	54	53	53	56	75	56	61
Number of passes at Annual Examinations and Supplementary Examinations as a per cent. of B	81	76	81	82	95	71	81	89	83	80

TABLE VII

STUDENTS SITTING FOR ANNUAL EXAMINATIONS.
1964-1966.

Course	Kalgoorlie						Norseman					
	1964		1965		1966		1964		1965		1966	
	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	101	88	76	95	73	96	3	67	1	100	....	....
Certificate	65	78	58	66	46	61	9	100	13	85	11	82
Technician	28	61	18	67	20	60	8	87	31	68	26	85
No Set Course	135	50	123	53	101	54	39	89	5	80	14	57
	329	68	275	68	240	69	59	81	50	74	51	76

TABLE VIII
COURSES COMPLETED 1962-1966 KALGOORLIE AND NORSEMAN

	1962	1963	1964	1965	1966
Associateship Courses—					
Mining	1	3	10	4	4
Metallurgy	2	1	2	2	5
Engineering	3	2	8	6	5
Mining Geology....	4	1	....	3	2
	10	7	20	15	16
Certificate Courses—					
Assayer's	6	1	6	4	4
Mine Manager's....	1	2	4	1	....
Mine Surveyor's	6	5	3	10	1
Engineering Draughtsman's	2	4	8	6	7
Electrical Engineering	1	....	1	....	....
Mechanical Engineering	1	....	1	....	....
	17	12	23	21	12
Technician Courses—					
Engine Operation and Maintenance	1	1	....	....	....
Workshop Foreman's	1	....	1	....	....
Welding	....	1	3	1	1
Workshop Practice (Mechanical)	....	....	....	1	3
Workshop Practice (Electrical)	....	....	....	....	....
Mine Manager's (2nd Class)	....	....	1	2	2
	2	2	5	4	6

TABLE IX
WORK DONE ON SAMPLES RECEIVED FROM PROSPECTORS AND OTHERS KALGOORLIE

	1962	1963	1964	1965	1966
Assay—gold	325	239	261	209	183
Assay—gold and other constituents	11	15	4	9	16
Assay—metals other than gold....	46	57	20	54	553
Assay plus mineral determination	11	....	11	18	3
Mineral examination	138	108	100	136	356
Rejected or transferred to Metallurgical Laboratory pay	30	39	23	16	72
	561	458	419	442	1,183

TABLE X
KALGOORLIE METALLURGICAL LABORATORY SUMMARY OF WORK

	1962	1963	1964	1965	1966
Investigations outstanding (January 1)	6	5	6	3	3
Investigations asked for (737-740)	5	5	4	2	4
	11	10	10	5	7
Investigations completed (737, 738)	5	3	7	2	2
Investigations outstanding (728, 736, 739, 740)	5	6	3	3	4
Investigations cancelled (729)	1	1	....	....	1
	11	10	10	5	7
Certificates issued	391	414	406	275	311

School of Mines of Western Australia.

APPENDIX 1.

ANNUAL EXAMINATION.

1966

Pass List

Kalgoorlie.

Passes are in order of merit.

(E) denotes equal.

(*) denotes year fee scholarship.

Chemistry P

Credit:

*Doyle, P. J.
Compton, S. G.
E {Chegwidden, P. J.
{Rendell, T. S.
Hennessy, G. T.

Pass:

Caudwell, L. H.
Muskett, L. G.
Abatematteo, G.
Bussell, D. M.
Cox, G. C.
Ball, B. N.
Russell, C. W.
Bowman, G. J.
Jamieson, L. K.

Supp. Exam. Granted:

Cavallaro, V.

Chemistry Q

Pass:

Gilbert, N. B.
Sweet, K. A.
Siefken, T. C.
Golding, P. D.

Chemistry 1

Pass:

Molloy, L. J.
Griffin, W. C.
Livingstone, G.
Holly, W. J.
Stokes, M. C.

Supp. Exam. Granted:

Smith, G. M.

Chemistry 2

Credit:

*Dunstan, P. L.

Pass:

Mykytiuk, A.
Rear, B. J.

Analytical Chemistry 1

Credit:

*Mykytiuk, A.
Fiegert, J.

Pass:

*Dunstan, P. L.
Symons, J. W.

Analytical Chemistry 2

Pass:

Faulkner, D. A.
E {Dombrose, E. J.
{Tillotson, D. L.
Brinsden, W. K.

Mineral Dressing 1

Credit:

*Tennant, T.
Fradd, J. F.

Pass:

Maley, R. L.
Tastula, R. A.
Griffin, W. C.
Zamorski, G.

Mineral Dressing 2

Credit:

*Dunstan, P. L.
Mykytiuk, A.

Pass:

Symons, J. W.

Mineral Dressing 3

Pass:

Wills, M. F.
Dombrose, E. J.
Tichelaar, P. D.

Chemical Metallurgy 1

Credit:

*Dunstan, P. L.

Pass:

Rear, B. J.
E {Mykytiuk, A.
{Symons, J. W.

Chemical Metallurgy 2

Credit:

*Wills, M. F.
Dombrose, E.J.
Tichelaar, P. D.

Pass:

Head, D. J.
E {Faulkner, D. A.
{Botica, G. G.

Physical Metallurgy

Credit:

*Wills, M. F.

Pass:

Dombrose, E. J.
Rear, B. J.
Tichelaar, P. D.
Head, D. J.
Symons, J. W.
Faulkner, D. A.
Botica, G. G.

Assaying

Credit:

*Lethlean, W. R.

Pass:

Smith, G. M.
E {George-Kennedy, R. J.
{Zamorski, G.
Griffin, W. C.

Supp. Exam. Granted:

Tastula, R. A.

Mathematics PA

Credit:

*Kitenbergs, J.
Flematti, P.

Pass:

E {Caudwell, L. H.
{Lee, G. S.
Compton, S. G.
E {Cox, G. C.
{Thompson, R. J.
Muskett, L. G.
Bussell, D. M.
E {Cruickshank, D. F.
{Curnow, P. R.
Southern, B. J.

Mathematics PB

Credit:

*Biltoft, P. J.
Caudwell, L. H.
Lee, G. S.

Pass:

Flematti, P.
Kitenbergs, J.
Thompson, R. J.
Compton, S. G.
Muskett, L. G.
Cruickshank, D. F.
Cox, G. C.
E {Bussell, D. M.
{Cavallaro, V.

Mathematics QA

Credit:

*Rendell, T. S.
Doyle, P. J.

Pass:

Jardine, T. L.
Siefken, T. C.
E {Barron, T. D.
{West, A. D.

Mathematics QB

Credit:

*Rendell, T. S.
Holly, W. J.
Doyle, P. J.

Pass:

Hamilton, I. C.
Jardine, T. L.

Mathematics 1.1

Credit:

*Tate, D. M.

Pass:

Willis, L. G.
Brooks, T. E.
George, K. A.
Erbe, J.
E {Bowman, G. J. / Holly, W. J. / Muze, K. A.}
Zamorski, G.
Smith, G. M.

Supp. Exam. Granted:

Van Raven, T. W.

Mathematics 1.2

Credit:

*Field, I. C.
Tillotson, D. L.

Pass:

Wills, M. F.
Brooks, T. E.
E {George, K. A. / Lethlean, W. R.}
Mandara, E. D.
E {McKay, A. A. / Sweet, K. A. / Tate, D. M.}
Dunstan, P. L.
Loxton, I. W.

Supp. Exam. Granted:

Rear, B. J.
Willis, L. G.

Mathematics 1.2
(Stat. section only)

Credit:

E {*Brooks, T. E. / *Sweet, K. A.}
McKay, A. A.

Pass:

Dunstan, P. L.
Field, I. C.
E {Lethlean, W. R. / Phillips, K. J.}
E {Loxton, I. W. / Symons, J. W.}
George, K A
Tate, D. M.
Mandara, E. D.
Bayly, J.
E {Rear, B. J. / Willis, L. G.}
Haule, E. F.
E {Johnson, D. C. / Tillotson, D. L.}
Mykytiuk, A.
E {Sloan, R. B. / Ward, W. S.}
Wills, M. F.

Supp. Exam. Granted.

Griffin, R. J.
Lockyer, P. C.

Mathematics 2

Pass:

May, A. J.
Bussell, L. M.

Supp. Exam. Granted:

Brioschi, D. G.
Dombrose, J. S.
Golding, P. D.

Physics Q

Pass:

Chamberlain, E. H. M.
Bostelman, L. E.
Curran, B. G.
Pivac, A. M.

Physics 1.1

Pass:

Holly, W.
George, K. A.
Tate, D. M.
E {Rear, B. J. / Willis, L. G.}
Kew, L. J.
Brooks, T. E.
Sweet, K. A.
Bowman, G. J.

Physics 1.2

Credit:

*Field, I. C.

Pass:

Brooks, T. E.
Tate, D. M.
Gilbert, N. B.
E {George, K. A. / Holly, W. J.}
Willis, L. G.
Kew, L. J.

Physics 2

Pass:

May, A. J.
Bussell, L. M.
Golding, P. D.
Brioschi, D. G.
Griffin, R. J.

Electronics

Credit:

*Marshall, D. A.
Field, I. C.
McKay, A. A.

Engineering Drawing P

Credit:

*Cox, G. C.
E {Caudwell, L. H. / Flematti, P.}
Bannister, W. E.
Muskett, L. G.

Pass:

Matthews, B.
Stretton, A
Tennant, T.
Cavallaro, V.
McVicar, K. J.

Engineering Drawing Q

Credit:

*Chegwidden, P. J.
Sloan, R.
Cruickshank, Miss M. R.
Rendell, T. S.

Pass:

Mandara, E. D.
Abatematteo, G.
Favis, G. D.
Clark. G. M.
Holly. W. J.
Tennant, T.

Engineering Drawing 1

Credit:

*Bowman, G. J.
Crew, R. J.
Wearne, J. M.
Brooks, T. E.
Tate, D. M.

Pass:

Clark, G.
Mahalingham, S. S.
Banks, F. R.
Sweet, K. A.
Mandara, E.
Lewis, C. J. B.
Erbe, J. D.
Tennant, T.

Engineering Design

Pass:

Wallis, H. W.
Bayly, J. G.
E {Foxton, A. J. / Miller, T. D.}

Machine Design 1.1

Pass:

Bayly, J. G.
E {Brioschi, D. G. / Foxton, A. J.}
Miller, T. D.

Machine Design 1.2

Pass:

Ward, W. S.
Dombrose, J. S.

Mechanical Engineering 1

Credit:

*Field, I. C.
Mandara, E. D.
Phillips, B. M.

Pass:

Wallis, H. W.
Haule, E. F.
Cluss, W. W.
E {Bayly, J. / Dobson, W.}
Tennant, T.
Powell, P.
E {Brioschi, D. G. / Foxton, A. J.}
Loxton, I. W.
Miller, T. D.
Banks, F. R.

Mechanical Engineering 2

Credit:

*Marshall, D. A.
Kelly, J. P.

Pass:

E {May, A. J. / Woolhouse, M. L.}
Cumming, G. M.
Hobson, J. C.
Dombrose, J. S.
King, R. M.

Electrical Engineering 1

Pass:

Tennant, T.
Mandara, E. D.
Tichelaar, P. D.
Dunstan, P. L.
Wallis, H. W.
Phillips, B. M.
Haule, E. F.
Wills, M. F.
Cluss, W. W.
Loxton, I. W.

Electrical Engineering 2.1

Credit:

*Carroll, G.
Woolhouse, M. L.

Electrical Engineering 2.2

Credit:

*Marshall, D. A.
Kelly, J. P.
Cumming, G. M.
Woolhouse, M. L.

Structural Engineering 1

Credit:

*Phillips, B. M.

Pass:

Brioschi, D. G.
E {Mahalingham, S. S. / Miller, T. D.}
Foxton, A. J.

Supp. Exam. Granted:

Banks, F. R.
Bussell, L. M.
Cluss, W. W.

Structural Engineering 2.1

Credit:

*Carroll, G. R.

Pass:

May, A. J.

Structural Engineering 2.2

Credit:

*Woolhouse, M. W.

Pass:

Cumming, G. M.

Hydraulics

Credit:

*Marshall, D. A.

Pass:

Carroll, G. R.
May, A. J.
Brioschi, D. G.

Supp. Exam. Granted:

Hobson, J. C.

Materials of Construction

Credit:

*Bowman, G. J.
Tate, D. M.
Field, I. C.
George, K. A.

Pass:

Brooks, T. E.
Willis, L. G.

Supp. Exam. Granted:

Brioschi, D. G.

Workshop Practice 1

Pass:

George, K. A.
Field, I. C.
Tate, D. M.
Brooks, T. E.
Cumming, G. M.

Internal Combustion Engines

Pass:

Brokenshire, A. H.
Major, T. A.
Condren, B. D.
Armstrong, G. I.
Rogers, R. D.
Muze, K. A.

Welding A

Pass:

Nettle, G.
E {Burns, J. T. / Major, T. A.}
Tyler, P.
Southern, B. J.
Cotterell, B.
Rowe, B.
McVicar, K. J.
Favis, D. J.
Felton, K.

Passed Practical:

Bowden, P.
Fry, W.
Mason, T.
McCahon, S. W.
McGinty, P.
Paul, C.
Purvis, P.

Welding B

Credit:

*Crocos, A. J.

Pass:
Marmion, E.
Morris, D. G.
Pearce, W.
Edmonds, G. S.
Passed Practical:
Vitucci, V.

Engineering Drawing W
Credit:
*Rowe, B.
Pass:
Tyler, P. J

English P
Pass:
Biltoft, P. J.
Van Raven, T. W.
Edwards, R. J.
E {Lee, G. S.
{Flematti, P.
Guise, C. J.
Cruickshank, D. F.

English Q
Credit:
*Crew, R. J.
Pass:
Bostleman, L. E.
Sweet, K. A.
Rojo, K. H.
E {Cox, G. C.
{Symons, J. W.
Kew, L. J.
Muskett, L. G.
Clark, G. M.
Supp. Exam. Granted:
Maher, P. M.

English 1
Credit:
*Carroll, G. R.
Pass:
Tennant, T.
Dunstan, P. L.
E {Maley, R. L.
{Woolhouse, M. L.
Fradd, J. F.
Willis, L. G.
E {Dombrose, J. S.
{Faulkner, D. A.
Tastula, R. A.
Brinsden, W. K.

Geology Q
Credit:
E {*Smith, G. M.
{*Siefken, T. C.
Pass:
Marshall, J. H.
Tate, D. M.
Zamorski, G.
Brown, R. J. M.
E {Cox, G. C.
{Goode, M.
E {Kitenbergs, J. A.
{King, J. L.
{West, A.
Rojo, K. H.

Geology 1.1
Pass:
Lethlean, W.
E {Griffin, W. C.
{Zamorski, G.
E {Rear, B. J.
{Molloy, L. J.
E {Tastula, R. A.
{Muze, K. A.
{Smith, G. M.
Phillips, K. J.
Griffin, R. J.
Lithgow, J. R.
Johnson, D. C.
Moriarty, M. E.
Mainwaring, D. D.

Geology 1.2
Pass:
Crew, R. J.
Phillips, K. J.
Mandara, E. D.
Johnson, D. C.
Supp. Exam. Granted:
Muze, K. A.

Geology 2.1
Pass:
Maley, R. L.
Fradd, J. F.
Phillips, B. M.
George-Kennedy, R. J.

Geology 2.2
Credit:
*Fradd, J. F.
Pass:
Maley, R. L.
Phillips, B. M.
Lewis, R. P. J.
Powell, P.

Geology 2.3
Credit:
*Dombrose, E. J.
Pass:
Brinsden, W. K.

Mining A
Credit:
*Goode, M.
Siviour, M. A.

Mining 1
Pass:
E {Lockyer, P. C.
{Maley, R. L.
Johnson, D. C.
Mainwaring, D. D.

Mining 2.1
Credit:
*Tennant, T.
Pass:
Phillips, K. J.
Haule, E. F.
Tastula, R. A.
Mandara, E. D.
Mainwaring, D. D.
Johnson, D. C.
Lewis, R. P. J.

Mining 2.2
Pass:
Crew, R. J.
Mandara, E.
Haule, E. F.
Tastula, R. A.

Mining 3
Credit:
*Phillips, B. M.
George-Kennedy, R. J.
Mahalingham, S. S.
Pass:
Lewis, C. J. B.
Lea, R. J.
Tennant, T.

Mine Ventilation
Credit:
*Phillips, B. M.
Pass:
Tennant, T.
Lockyer, P. C.

Surveying 1
Credit:
*Maley, R. L.
Pass:
Lockyer, P. C
Field, I. C.
Brown, R. J. M.
Ward, W. S.
Muze, K. A.
Van Raven, T. W.
Passed Practical:
Erbe, J. D.
Hobson, J. C.
Supp. Exam Granted:
King, R. M.

Surveying 2.1
Credit:
*Sweet, K. A.
Tastula, R. A.
Pass:
Haule, E. F.
Supp. Exam. Granted Paper B:
Mandara, E. D.

Surveying 2.2
Credit:
*Pivac, A. M.
Pass:
Mandara, E. D.
Tastula, R. A.

Metallurgy A
Pass:
Drazic, K. W.

SCHOOL OF MINES—NORSEMAN.
ANNUAL EXAMINATIONS

Pass List.

Chemistry P
Credit:
*Perkin, R. E.
Pass:
Churchill, W. G.
Wells, P. H.
Bermingham, M. J.
Van Gelderen, F. P.
Stewart, B. A.

Mathematics PA
Pass:
Bermingham, M. J.
Fleay, J. R.
Jones, H. B.

Mathematics QA
Credit:
*James, M.
Pass:
Underwood, G. A.
King, P.
Wells, P. H.

Mathematics QB
Pass:
Beattie, R. J. S.

Physics Q
Pass:
Beattie, R. J. S.
Perkin, R. E.
Denison, J. L.
E {Churchill, W. G.
{King, P.

Engineering Drawing P
Pass:
Wells, P. H.
Lahti, R. K.
Koops, E. P.

Engineering Drawing Q
Credit:
*James, M.
Pass:
Beattie, R. J. S.
Denison, J. L.
Clarke, G. M.
Ismail, K. G. R.
King, P.

Welding A
Credit:
*Nazzari, P. F.
Lahti, R. K.
Pass:
Jones, H. B.
Eyre, H. R.
Fleay, J. R.
Ismail, K. G. R.
Morgan, T. A.
Jenkins, R. L.
Darch, R. J.

Engineering Drawing W
Pass:
Clarke, G. M.
Nazzari, P. F.
Stewart, D. A.

Geology 1.1
Pass:
Denison, J.

Geology 1.2
Pass:
Denison, J. L.
Swain, G. B.

Mining A
Pass:
Shave, D. A.
Lahti, R. K.

Mining 1
Pass:
Beattie, R. J. S.
Eyre, H. R.
Supp. Exam. Granted:
James, M.

Surveying 2.2
Pass:
O'Connor, G.
Stewart, B.A.

Workshop Practice B
Pass:
E {Fleay, J. R.
{Morgan, T. A.
Van Gelderen, I. M.
Jenkins, L. K.
Ismail, K. G. R.

Workshop Practice C
Credit:
*Stewart, D. A.
Pass:
Perkin, D. A.
Giles, T. E.
Phillippe, G. R.
Jones, H. B.

Metallurgy A

Pass:

James, E. P.
Clarke, G. M.
Sloan, G. K.
Perkin, D. A.
Horan, R. J.
Phillippe, G. R.
McEwan, G. S.
Stewart, D. A.

Electrical Theory B

Credit:

*James, E. P.
Perkin, R. E.

Pass:

Horan, R. J.

Electrical Drawing A

Pass:

Colli, J. P.
Sloan, G. K.

Electrical Drawing B

Pass:

Horan, R. J.
James, E. P.

SUPPLEMENTARY EXAMINATIONS.

FEBRUARY, 1966.

The following students passed in the subjects listed below:

KALGOORLIE.

Mathematics 1.1
Renton, K. J.

Mathematics 1.2
Tastula, R. A.

Mathematics 2
Cluss, W. W.

Electrical Engineering 2.1
McRostie, B. L.

Mining 1
Stodart, I. S.

Mining 2.1
Muze, K. A.

NORSEMAN.

Surveying 1
Churchill, W. G.

SCHOOL OF MINES OF WESTERN AUSTRALIA.

APPENDIX 2.

SCHOLARSHIPS AND PRIZES, 1966.

CHAMBER OF MINES PRIZES:

Metallurgy: Mykytuik, A.
Mining: Lockyer, P. C.
Engineering: Field, I. C.
Geology: Molloy, L. J.

SCHOOL OF MINES STUDENTS' ASSOCIATION SCHOLARSHIPS

Mining: Crew, R. J.
Metallurgy: Lethlean, W. R.
Engineering: No Award.
Geology: Fradd, J. F.

INSTITUTE OF MINING SURVEYOR'S PRIZE:

$20 Prize: Maley, R. L.
$10 Prize: Sweet, K. A.

SOCIETY OF THE W.A. SCHOOL OF MINES ASSOCIATES' PRIZE:

Rendell, T. S.

REG DOWSON SCHOLARSHIPS:

Group A: —.
Group B: Fleay, J. R.
Horan, R. J.

ROBERT FALCONER PRIZES:

First Prize ($10): Compton, S. G.
Second Prize: Lee, G. S.

C. A. HENDRY:

Erbe, J.

WESLEY LADIES GUILD:

Chegwidden, P. J.

APPENDIX 3.

KALGOORLIE METALLURGICAL LABORATORY.

by

E. Tasker, A.W.A.S.M. (Met.), A.M.Aus.I.M.M.
Senior Research Metallurgist

INTRODUCTION.

Two reports of investigations and three hundred and eleven certificates of testing or analysis were issued during the year. Brief descriptions of the investigations are included in the report.

For further information regarding these reports apply to:

The Secretary,
Commonwealth Scientific and Industrial Research Organisation,
314 Albert Street,
East Melbourne, C.2.
Victoria.

from whom copies of the reports can be obtained, usually six months after date of issue.

In addition to the reports issued, two other investigations were approved and test-work was in progress.

COMPLETED INVESTIGATIONS.

Report No. 737.

Test-work was carried out on cassiterite bearing eluvium from the Hartigan and Strawberry Creek areas of the Cooglegong Tin field, Pilbara. Test results indicated that the cassiterite could be readily recovered by jigging.

Report No. 738.

Flotation tests were carried out on samples of oxide and sulphide copper ores from Warridar, W.A.

INCOMPLETE INVESTIGATIONS.

Report No. 728.

No further work has been carried out on this investigation since issue of an interim report.

Report No. 729.

Cancelled. (Paris Gold Mine, Widgiemooltha.)

Report No. 736.

Test-work in progress on a lead ore from the Mary Springs Lead Mine, near Geraldton, W.A.

Report No. 739.

Flotation tests on sulphide sulphur ore from Norseman, W.A.

Report No. 740.

Testing of cement stabilised wind-blown sand for use as underground backfill at Kambalda, W.A.

E. TASKER,
Senior Research Metallurgist.

KALGOORLIE METALLURGICAL LABORATORY

Summary of Year's Work, 1966.

Report No.	Owner	State	Locality	Ore Type	Type of Investigation	Confidential Until	Number of Metallurgical Tests	Number of Assays	
								Gold	Other
737	Cooglegong Tin Pty. Ltd. Perth	W.A.	Cooglegong	Tin gravel	Gravity concentration tests	8/1/67	10	....	20
738	R. W. Shearer, South Perth	W.A.	Warridar	Oxide - sulphide copper ores	Flotation tests	16/3/67	12	....	30
....	Certificate Nos. 3203 to 3477 3479 to 3514	....	....	....	....	....	....	605	942
....	Free Assays	....	....	....	....	....	....	193	700
						Totals	22	798	1,692

THE FOLLOWING INVESTIGATIONS WERE INCOMPLETE OR PENDING AT DECEMBER 31, 1966 :—

Report No.	Owner	State	Locality	Ore Type	Type of Investigation	Confidential Until	Number of Metallurgical Tests	Gold	Other
728	Swan Portland Cement, Perth	W.A.	Fremantle	Cement lime-rock	Beneficiation	....	12	....	76
729	Cancelled.								
736	T. A. Bridson, Geraldton	W.A.	Mary Springs Lead Mine	Galena ore	Concentration tests	....	4	....	20
739	Norseman Gold Mines N.L., Norseman	W.A.	Norseman	Pyrite-Pyrrhotite ore	Flotation tests	....	30	....	100
740	Western Mining Corporation, Kalgoorlie	W.A.	Kambalda	Wind-blown sands	Stabilised backfill	....	10	....	20
						Totals	78	798	1,908

DIVISION VI

Annual Report of the Inspection of Machinery Branch of the Mines Department for the Year 1966

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 1966.

A. Y. WILSON,
Chief Inspector of Machinery.

Section 1.

INSPECTION OF BOILERS, MAINTENANCE, ETC.

(See returns Nos. 1, 2 & 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 lbs. to the square inch, and having a capacity exceeding five cubic feet; but does not include containers used for transport;

(c) any vessel used under steam pressure as a digester; and

(d) any steam jacketed vessel used under steam for boiling, heating, or disinfection purposes.

It also includes the setting, smoke stack, and all fittings and mountings, steam or other pipes; feed pumps and injectors and other equipment necessary to maintain the safety of the boiler.

Return No. 1.

In this return is recorded the number of boilers of the various types added to our registrations during the year; those of Western Australian origin exceed by 67 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 3040 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 to other Australian States shows a decrease of approximately 20% compared with 1965. Ninety two were sent to the Eastern States. Imports of boilers and pressure vessels from the Eastern States and other countries both show a marked increase. The former approximately 20% and the latter 30%.

Once again the exports are almost entirely from one firm making package boilers. Imports apart from several large water tube boilers are mainly in the pressure vessel field. They would be mainly L.P. Gas Receivers which are made in quantity and therefore cheaper in other states, thus cutting out the local manufacture.

As predicted industrial expansion continued in W.A. with iron ore mining and shipping coming into production at three centres. Existing plants at the alumina refinery, oil refinery, and fertilizer complex continued to expand. Many smaller industries were established or expanded.

MAINTENANCE AND MISCELLANEOUS.

Maintenance and operation of boilers during the year have generally been of a high standard. There are of course the usual exceptions. Water treatment seems to be better understood and more efficiently applied.

Unfortunately staff has again been insufficient to permit the number of working inspections on boilers which are considered desirable.

The usual high standard of workmanship expected by this Branch has been generally maintained by boiler and pressure vessel manufacturers in this State. It is noted that some manufacturers are rating the output of their boilers right up to the maximum under optimum conditions. As it is almost impossible to get optimum conditions in actual practice this can lead to trouble when the user wishes to get the maximum rated output from the boiler. Perhaps manufacturers should not be so optimistic in their claims or should leave a greater margin for lost efficiency under service conditions.

The number of boilers and pressure vessels registered increased by 474 during the year.

RETURN No. 1.

Showing the Number of Boilers of Each Type, and Country of Origin of New Registrations, for the Year ended 31/12/66.

	U.S.A.	United Kingdom	Eastern States	Japan	Norway	Germany	Sweden	Western Australia	Unknown Resource	Total
Return Multi. Stat. Intern. Fired	....	1	....	....	....	....	....	134	....	135
Cornish	....	....	....	....	....	....	....	7	....	7
Digester	....	....	9	....	1	....	....	12	....	22
Vulcaniser	2	....	8	16	....	....	....	....	2	28
Steam Jacketed Vessels	....	....	8	....	....	....	....	13	1	22
Sterilisers	....	....	12	....	....	2	....	37	....	51
Air Receivers	23	15	61	2	....	....	2	90	13	206
Gas Receivers	12	5	56	11	....	....	1	50	9	144
Autoclaves	....	....	1	....	....	....	....	1	....	2
Return Multi. Stat. U/fired	....	....	....	....	....	....	....	....	....	....
Vert. Stationary	....	1	1	....	....	....	....	....	....	2
Water Tube	....	....	3	....	....	....	....	....	....	3
Lorance	....	....	....	....	....	....	....	1	....	1
Cylindrical	....	....	....	....	....	....	....	....	....	....
Total	37	22	159	29	1	2	3	345	25	623

RETURN No. 2.

Showing Classification of various Types of useful Boilers in proclaimed Districts on 31/12/66.

Type of Boilers	Districts Worked from Perth	Districts Worked from Kal-goorlie	Total
Lancashire	32	27	59
Cornish	212	66	278
Semi Cornish	14	1	15
Vert. Stationary	395	44	439
Vert. Port.	30	12	42
Vert. Multi Stat.	39	4	43
Vert. Multi Port.	4	1	5
Vert. Pat. Tubular	49	....	49
Loco. Rect. F/Box Stat.	72	20	92
Loco. Rect. F/Box Port.	144	17	161
Loco. Circ. F/Box Port.	84	3	87
Locomotive	75	12	87
Water Tube	548	59	607
Ret. Multi U/Fired Stat.	254	8	262
Ret. Multi S. U/Fired Port.	....	5	5
Ret. Multi Int. Fired Stat.	318	12	330
Sterilisers	847	70	917
Autoclaves	114	2	116
Digesters	330	6	336
Gas Receivers	803	3	806
Air Receivers	2,627	798	3,425
Vulcanisers	475	11	486
Steam Jacketed Vessels	749	15	764
Not Elsewhere Specified	280	5	285
Total Registrations Useful Boilers	8,495	1,201	9,696
Total Boilers out of use, 31/12/66	2,220	820	3,040

RETURN No. 3.

Showing Operation in Proclaimed Districts during Year Ended 31/12/66.

Boilers	Districts Worked from Perth	Districts Worked from Kal-goorlie	Totals	
			1966	1965
Total number of useful boilers registered	8,495	1,201	9,696	9,222
New Boilers registered during year	617	6	623	693
Boilers inspected thorough	5,256	347	5,603	5,540
Vessels exempt under Act constructed for export thorough	....	....	....	161
Boilers inspected working	1,019	34	1,053	1,199
Boilers condemned during year temporarily	2	....	2	1
Boilers condemned during year permanently	52	1	53	77
Boilers sent to other states during year	92	....	92	115
Boilers sent from other states during year	148	3	151	123
Boilers sent from other countries during year	95	3	98	66
Boilers sent to other countries during year	1	....	1	10
Transferred to other Departments	3	....	3	1
Transferred from other Departments	1	....	1	2
Re-instated	1	....	1	....
Converted	....	....	....	....
Number of notices of repairs issued during year	637	49	686	624
Number of certificates issued including those issued under Section 30 during the year	5,313	358	5,671	5,555

Section 2.
EXPLOSIONS AND INTERESTING DEFECTS.

I am pleased to be able to report again this year that no boiler or pressure vessel explosion occurred. There were however several incidents and some interesting defects discovered worthy of report.

Case "A".

The vessel concerned in this case history was a single shell autoclave 16" diameter × 30" long, fitted with a radial arm locking device on the door. It was installed in the sterilizing room of a large hospital. This vessel was involved in two very similar mishaps in approximately seven months. In the first instance a load of sterilizing had been put through the cycle and was ready to be taken out. A nursing aide tried to open the door but found it difficult to turn the wheel. She then called another person to assist with the opening. Apparently they were successful for the door suddenly flew open expelling the contents including the dressing drum tray, which struck one of the operators in the throat inflicting quite severe injuries.

When the investigation was made it was stated by the uninjured nurse, who opened the door, that steam had been shut off the vessel prior to opening the door and no pressure was showing on the gauge. However the inspector and hospital engineer put the vessel under pressure again and could find no defect in the control valves, safety valve or pressure gauge. It is almost certain that the door was opened while still under pressure. In an effort to avoid a recurrence of this a spring loaded safety latch was fitted to the opposite side of the door frame from the hinge so that this would or should engage if the door locking arms were disengaged again under pressure. This vessel did not have a pressure diaphragm locking device in the door.

Approximately six months later this Branch was again advised that this same autoclave door had been opened while still under steam. In this case the nurse had opened the door and released the safety latch while pressure still showed on the gauge and without turning the control handle to release or opening the vent cock on the door. As a result the door bust open and was torn from its hinges. Fortunately the nurse who opened it suffered only minor burns and did not even have to go off duty.

The lesson to be drawn from this incident seems to be that any safety or interlock device to be effective must be designed and fitted so that it operates automatically, is not dependent on and cannot be interfered with by any outside agency. This is especially necessary when the operators are unaware of the hazards and unskilled in a mechanical sense, in the use of such vessels.

Case "B".

This incident again concerns an autoclave but somewhat different in that it is 6ft. in dia. × 70 ft. long and is used in industry for curing asbestos cement products. Again the door blew open but without injury to anybody. The attendant when questioned, gave the following account of the matter—

> The autoclave had been unloaded, and as the next load was not ready he closed the door, jacked it around onto the castellations, inserted the locking pin and closed all vents. The steam inlet valve was shut. Approximately 2½ hours later some material arrived for curing. The operator removed the locking pin and as the safety whistle did not blow he started to jack the door around without opening the vents. When it was almost off the castellations the whistle started to blow very slightly. He stopped pumping the jack and a few seconds later the door blew open.

Fortunately the operator was crouched beside the autoclave operating the jack and escaped injury. He advanced the theory that the stop valve was leaking but inspection did not show this. It is possible the valve was not shut down hard. However no attempt should have been made to open the door without opening the vents. With a door this size even 1 p.s.i. in the vessel exerts a force of almost two tons, trying to push it open. As a further safeguard to indicate when pressure, possibly too low to register on the pressure gauge is in the vessel a manometer has now been fitted to it. The manometer is brought into connection with the autoclave by operation of a cock prior to attempting to open the door.

Case "C".

This concerns two similar water tube boilers with working pressure of 960 p.s.i. and a rating of 175,000 lbs. per hour.

The history of these boilers begin with their installation and commissioning in 1963. At that time the boiler installation was more than adequate for the demands on it. However by 1965 further processing plant had been installed and the steam demand had increased so that the rated output was required. After working at full capacity for a few months leakage of tubes was detected in one boiler. Four tubes were found blistered or holed through. These were repaired but three months later one tube was found to be holed through and six showed blistering. Internal inspection of the steam and water drum showed considerable wastage from what appeared to be erosion. The tubes were repaired or replaced as necessary and the drum was treated with apexior. At further intervals of approximately three months more tube trouble of the same nature and in the same areas, was experienced. Re-inspection of the drum did not show any further deterioration.

The tube trouble continued until mid 1966 when it was decided by the owners to reduce the steam output of the boilers considerably below the maker's rating. To do this production was curtailed. At the reduced output the boilers have functioned satisfactorily.

Our investigations of the tube leakage showed that a light scale was depositing on the water side, causing overheating and bulging. When the boiler was working below rated capacity this was not critical but as soon as full steaming was demanded the trouble began. For deposits to form there must be impurities in the water but there could also be some lack of circulation. The wasting of the sister boiler follows a similar pattern.

I feel that when planning of large projects, or any project for that matter, is undertaken it is unwise to count on 100% rated output as continuous service output. Some reservation should be put on makers' claims and some margin left for working under less than ideal conditions. The importance of efficient water treatment in fast steaming high output boilers cannot be overstressed. The return of condensate from process vessels to be reused as feed water needs careful evaluation and analysis to ensure that all impurities can and will be extracted before it is again fed into the boilers.

Case "D".

In this report I am combining two examples of sprung and leaky tubes. The first refers to a multi-tubular internally fired package boiler. This is a repetition of trouble experienced and reported several times in the last few years where the boiler is subjected to heavy peak loadings when steam is required to fill large autoclave type vessels. In this instance I advance the same reasons as before, having had no further information to cause revision of opinion. To reiterate, sudden heavy demands, boiler onto high fire, turbulence and steam insulation causing overheating of tubes and tube plate with consequent springing of tube expansions and leakage. An automatic steam draw regulating valve is being fitted to this installation.

The second instance refers to a multi-tubular under fired oil fired used in a processing plant. It was the habit of the man in charge of this boiler to pump it up to a full glass prior to shutting down. Unbeknown to him, after he had gone, others in the factory were in the habit of drawing hot water off through the blow down for washing down purposes. It appears that the blow down was not closed properly, during the night the boiler drained itself, and when the fireman returned in the morning he flashed up the burner without checking his water level. Over-heating and leaking tubes resulted.

Several fairly classical points illustrating what not to do in boiler operation are evident in this report—

(1) The drawing off of hot water direct through the boiler blow down is not good practice.

(2) If this must be done it should only be by the person in charge of the boiler.

(3) The person in charge of the boiler committed the cardinal sin of failing to check the boiler water level before lighting up.

Section 3.

INSPECTION OF MACHINERY.

(See Returns Nos. 4, 5 and 6)

At the expiration of the year 54,162 groups of machinery were registered. This is an increase of 1683 groups compared with 1965. Lift and escalator figures show an increase of 44 installations.

Accidents to Machinery.

As was the case last year most machinery accidents investigated, unfortunately, involved persons and personal injury. Cranes again were the main section in which machinery accidents occurred from the usual causes of overloading, overturning while moving on rough ground, and in one instance, when moved too close to the edge of an embankment which collapsed.

One case of a jib failure due to overloading concerned a crane with an 80 ft. jib driven and in a large part designed by the owner. The design had been discussed with officers of this Branch and shortcomings and suspected design weaknesses, in view of the loads requested, had been pointed out to the owner. It was arranged that the crane be taken to the test area for testing and evaluation, but when the inspector arrived at the test area at the appointed time he found the machine there with a collapsed jib. It transpired that the owner had arrived early and decided to start testing at the loads and radii he considered applicable. The results were as had been predicted by this Branch.

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 1966.

	Districts Worked from Perth	Districts Worked from Kalgoorlie	Totals	
			1966	1965
Number of groups driven by Steam Engines	117	367	484	489
Number of Groups driven by Oil Engines	3,902	897	4,799	4,773
Number of Groups driven by Other Power	134	196	330	315
Number of Groups driven by Electric Motor....	44,756	3,792	48,548	46,902
Totals	48,909	5,252	54,161	52,479

RETURN No. 5.

Showing operations in Proclaimed Districts during year ended 31st December 1966.
(Machinery only)

——	Districts Worked from Perth	Districts Worked from Kalgoorlie	Totals	
			1966	1965
Total Registrations Useful Machinery	48,910	5,252	54,162	52,479
Total Inspections made	30,973	3,851	34,824	30,441
Certificates (Bearing Fees)	5,770	523	6,293	5,940
Notices issued (Machinery Dangerous)	664	45	709	568

RETURN No. 6.

Showing Classification of LIFTS on 31st December 1966

Types	How Driven	Totals	
		1966	1965
Passenger	Electrically Driven	366	357
Passenger	Electric Hydraulic Driven	22	13
Goods	Electrically Driven	127	124
Goods	Electric Hydraulic Driven	10	9
Service	Electrically Driven	150	136
Service	Electric Hydraulic Driven	4	3
Escalators	Electrically Driven	46	39
		725	681

Section 4.

PROSECUTIONS FOR BREACHES OF THE ACT.

One prosecution for use of an unregistered crane has been initiated but has not come to court yet.

Section 5.

ACCIDENTS TO PERSONS.

Return 7 and 7a record accidents to persons in which machinery subject to the Act was involved, the former relating to those of a serious nature and the latter to incidents classified as being of a minor nature.

Return 7b shows accidents caused by machinery not subject to registration by this Department but investigated under the provisions of Sec. 50 of the Act.

The overall total of occurrences shown in the three returns numbers 155.

During the year 6 fatalities occurred involving cranes or lifting gear and one concerning a lift.

Case A.

This accident resulted in a fatality and to accentuate this misfortune the victim was not really concerned with the job in hand but was a bystander giving assistance.

The accident occurred when a mobile 10 cwt. builders platform hoist was to be moved on site, dismantled for travelling and then taken to another site. To do this a mobile crane had been hired to pick the hoist up in its vertical position near a wall, move it to a clear space where the tower section would have space to be laid over in a horizontal position to be prepared for towing away.

The method employed to do this was as follows. The crane driver supplied a ½" diameter wire rope sling to the employee of the hoist hiring company and indicated that the sling should be reeved through the main chords of the hoist tower approximately 24 ft. from the head of the tower. The tower was 45 ft. long. When inquiries were made the two men concerned differed as to which way the sling was reeved. The hoist man said he placed the sling round two main chords nearest the crane. That is the two chords at one side. The driver says that the sling was through the two chords at the back of the tower, i.e. across the axis in which the tower was to be lowered. The latter would be the better position.

However, after reeving the sling and placing both eyes over the hook the hoist man had the crane take up the sack and then untied the manila rope which was used to tie the hoist tower to the building. This rope was left attached to the tower each end to be used as a tail rope in steadying the tower and later to pull the tower off balance to lay it down. The hoist man took one end of the rope, the deceased who was nearby took the other. The manoeuvre was successful until it was necessary to pull the crane off balance. During this operation the hoist man tried to shift his grip on the rope and allowed it to slacken off. This in turn allowed the hoist tower to swing up again. It was then the crane driver noticed one end of the sling had come off the hook. He shouted a warning but unfortunately the deceased ran along the line of fall of the tower and was struck by the top, suffering fatal head injuries.

The mishap was caused by one end of the sling coming off the hook thus allowing the hoist to fall. It is considered that the back swing of the tower was sufficient to cause one end of the sling to jump off the hook. If it was slung in the manner indicated by the hoist man it is quite likely that the sling could not adjust by sliding round the chords due to fouling the bracing. This point would not be critical had a safety hook been fitted to the crane or the hook had been moused.

Case B.

This accident, also fatal, concerns an overhead travelling crane and again the lifting gear and method of slinging are at fault.

At the time of the accident the deceased was assisting two other men to prepare a horizontal boring machine for a new job. In order to do this it was necessary to lift with an overhead crane and position three setting up tables on the bed of the machine. These setting up tables are large cast iron oblong blocks, hollow, with two sides machined with slots to take bolt heads when the work to be machined was bolted to them. The weight of approximately 25 cwt is not evenly distributed in the blocks.

The method employed to lift the tables was as follows—

> Two brackets made of angle iron with a hole in each leg were bolted through one leg at diagonally opposite points on one slotted face of the block. Shackles were secured through the other holes in the brackets. Hooks attached to slings were passed through the shackles. The other ends of the slings were attached to two holes in the corners of a heavy triangular plate. A large hole was cut in this plate to take the crane hook.

Investigations showed that just prior to the mishap two tables had been positioned and the third had been lifted by the crane. The victim was wiping over the section of the bed plate of the borer so that the third table would sit flat on it. Witnesses stated that he was not under the suspended load. At this stage the table commended to tilt further. It already had a tilt due to the unsymmetrical distribution of the weight in the table. One of the brackets slid towards the other allowing one end to drop till it hit the machine bed. Deceased was in the path of the table and it is thought that when the first end of the table hit the bed it jarred the other bracket loose and both became detached from it. The table then kicked forward and struck the victim.

We were unable to determine whether both brackets had been properly tightened down before the lift was made. Both witnesses who had attached the brackets said that they did. However the brackets did slide and become detached. It is certain that the method of slinging resulting in the tilted load was not satisfactory. The method has been revised and four suspension points are now used. This permits the load to remain horizontal.

Case C.

The machine involved in this fatal accident was a mobile jib crane. It was not in use at the time but was stationary with jib lowered to the horizontal for the purpose of shortening it, by removing the centre insert. The inspector who investigated reports as follows—

> From investigation it appears the the crane driver had lowered the jib to a horizontal position for the purpose of dismantling the jib and removing the 10′ insert. After lowering the jib the crane driver left the crane to make arrangements for refuelling, and he was not present at the time of the accident. The jib was composed of a 15′ butt section, 10′ insert and a 15′ head section, totalling 40′. These sections are of a box construction and are joined together with mating lugs and held in place with the boom joining pins at each of the four corners.
>
> It appears that before the arrival of a small mobile crane which was to support the jib during the dismantling operation the victim commenced to knock out the bottom jib connecting pins at the 25′ joining section. After knocking out the first bottom pin he commenced knocking out the second bottom pin. He was in a crouching position underneath the jib when knocking out this second pin. When this pin was freed, the jib collapsed, crushing him beneath it.

Photos were taken of the machine after the accident, before anything had been moved except the deceased, and from them it could be clearly seen that the jib was not satisfactorily supported for dismantling.

Two witnesses who were to assist in dismantling, were standing alongside the jib awaiting the arrival of the other crane at the time of the accident. They said that they did not expect the deceased to knock the pin completely out until the crane had arrived to support the sections.

Unfortunately to anyone who has had much to do with crane jibs which can be lengthened or shortened by the addition or removal of sections, this will be an old story. Even if the victim being close to the machine did not realise what would happen when he removed the bottom pins it should have been obvious to the witnesses standing by. The care needed to support these jibs for dismantling and correctly supporting them cannot be over-emphasised. A little time standing off and deciding where the support is needed and what will be the effect of removing the pins is well warranted.

Case D.

This accident was not fatal but did result in severe injuries to the victim. It is noted here because the potential danger of the operation is not immediately apparent and can be a trap for the unwary. The machine involved was an overhead gantry fitted with a pendant controlled 2-ton electric hoist. The victim, a fitter, and his mate were reassembling a punch and shears machine. They had all the main frame bolted in position and were fitting the top drive shaft to which the flywheel was attached. The fitter was standing on the machine bed, the assistant was operating the hoist which was attached to the flywheel by a sling. Just prior to the accident, fitting of the outboard pedestal bearing of the shaft was in progress. The shaft was already secured in the inboard bearings. In order to slide the pedestal bottom half of the bearing under the outboard end of the shaft the weight was taken by the hoist. This did not give sufficient clearance to insert the pedestal so a further attempt was made to hoist the shaft. As this was done the hoist support flanges fractured allowing the hoist drum, motor etc. to fall. In falling it struck the fitter, who was knocked off the machine and hit his head on the floor approximately 5 feet below. He suffered severe injuries.

The lesson to be learnt from this mishap to beware and be aware when there is likelihood of the imposition of an unknown load on lifting gear or machines. Neither the operator of the hoist nor the fitter knew what load was being imposed on the hoist as in the final analysis they could have been attempting to lift the whole machine and the concrete foundation.

The failure of the cast iron hoist support flanges, which had ample strength in direct tension, is believed to have been due to bending also being introduced when the mild steel suspension bar of the hoist, to which the flanges were attached, bent.

Case E.

There is nothing in the circumstances relating to this fatality which is not known to people experienced in the setting up and use of machinery but if by repetition even one person is made aware of some of the hazards associated with circular saws it will be worth while.

The machinery in question was a 22"dia. circular saw mounted on a home made bench and driven by a motor cycle engine. Its existence was unknown to this Branch and consequently it had not been inspected. After the saw burst while in use, killing the unfortunate victim, the circumstances were investigated by an officer of this Department.

He reports on the machine as follows—

> The 22 in. dia. circular saw was mounted on a bench of welded construction 3′1″ high by 3′ long and 2′ wide, with main frame members of ¾″ water pipe. The driving engine was mounted within the frame work on 2″ × 3/16″ flat steel plates. A 1″ dia. by 16″ long saw spindle was fitted into a length of 2″ water pipe, with sockets screwed to each end, which apparently housed the ball race bearings. This spindle housing was secured to the frame work directly below the table top. A single Vee belt drive was from a 6¼″ dia. twin pulley attached to the engine crankshaft, and a 4½″ dia. single pulley on the saw spindle.
>
> The circular saw was secured between two 4½″ dia. collars and locked on the spindle with a left hand thread nut. To locate and key the saw between the collars a ⅜″ dia. bolt was passed through holes in the collars and the saw blade and secured. A table top of ⅛″ m.s. plate was welded to the frame. Control of the engine was by a foot pedal operated throttle.
>
> There was approximately ⅛″ lateral movement in the saw spindle and some detectable wear in the bearings, for which no provision for direct lubrication had been made.
>
> The construction of the saw bench was such that the saw could not be removed for servicing by simply removing the nut on the saw spindle. It appeared that the removal of the saw also entailed either the cutting away of the weld metal securing the table top to the frame or the withdrawal of the saw spindle from the housing. This perhaps accounts for the deteriorated condition of the saw blade. It was blunt, badly set, cracked radially from the tooth gullets, and showed signs of overheating. I am of the opinion that it had not been removed from the machine for a considerable time.
>
> The engine speed when the accident occurred could have been in the vicinity of 5,000 revs. per min., a speed which is well within the capabilities of a motor cycle engine of this type. The ratio of the speeds of the saw spindle to the engine crankshaft was approximately 1½:1, through the pulley wheels fitted. This could have given the saw a speed of up to 7,500 revs. per min., equivalent to a peripheral speed of 43,000 feet per min. on the 22″ dia. saw. If only half this speed was in fact attained, the peripheral speed would have been in excess of 20,000 ft. per min. The recommended or safe speed for saws is 8,000—9,000 ft.
>
> It is apparent that the blunter the saw became, the more power the operator gave to the engine to make the saw cut through the wood. When this blade eventually burst, parts of it sliced through the ⅛″ steel plate of the bench top, cut through the exhaust pipe of the engine, and damaged other parts of the bench, all indicating the tremendous speed at which it must have been revolving.

Further comment on this mishap would be superfluous.

Case F.

This accident, which resulted in serious injury to the victim, shows the disproportionate results which can eventuate from the failure of a very small component in a machine.

The machinery involved in this accident was a bulk wheat ship loading gantry. The part directly concerned with the accident was a telescoping tubular chute through which grain was poured into the ship's hold. This chute can be extended or retracted inside a latticed boom which in turn can be raised and lowered for positioning. The estimated weight of the telescoping chute which is a 16″ dia. tube 39′6″ long made of ¼″ t. plate is approximately 22 cwts.

The telescoping arrangement consists of a winch drum, driven by a reversible electric motor through a reduction unit, mounted on top of the latticed angle iron boom. Both ends of the ½″ dia. wire rope are attached to the telescoping tube, and wound on the winch drum in such a manner that the telescoping tube can be pulled in either direction along the fixed boom. There are top and bottom limit switches and stops at the lower end of the fixed guide rails.

From enquiries it was found that the victim was on the ship which was being loaded, standing in line with and below the chute directing the grain into the hold. Without warning the top sheave pin snapped allowing the telescopic tube to run out under its own weight, snapping the wire rope against the angle iron bracing and crushing him against the hatch boards. The boom was positioned at an angle such that the tube crushed the injured party before it reached the stops at the end of the fixed guide rails. The piece of the sheave pin and the holes in the bracket were very badly worn and it is obvious the pin had been turning in the bracket and not in the sheave bush. The piece of sheave pin mentioned above was found just after the accident. The sheave with the body of the pin in it fell into the hold and was found when the cargo was dicharged. The head of the pin has not been recovered.

Examination of the sheave and the body of the pin showed conclusively that the pin was seized in the sheave bush and the sheave and pin had been revolving in the bracket thus accounting for the wear in the pin and its eventual fracture. When the pin body was removed from the bush, (it was found impossible to push it out even with a twelve ton pressure so that the bush had to be split) careful examination of the pin and bush was made. It was found that the grease hole in the pin was blocked solid at the outlet end. Grease was quite soft at the inlet end. Grease in bush grooves was dry and hard. There were some indications of wear in the bush showing that it had functioned normally for a time.

This accident shows the importance of attention to routine lubrication of all parts no matter how small and insignificant they may appear to be nor how awkward they are to get at. This question of accessibility of lubrication points is one which designers should carefully consider. Lubrication points should be located at central points if possible or if not ensure that there is some means of safe and easy access to all points. A hard to get at or hidden lubrication point will almost certainly be neglected with results such as are related in the foregoing.

Case G.

This accident, unfortunately fatal, concerns a lift installed in a warehouse. The main function of this machine was to transport goods between the basement and the fourth floor. Installed in 1905 the lift was far from modern being a belt drive with a rope control reached through a hole 30" × 14" in the side of the car. Adjacent to this is a push button station with a green button for starting the constant speed motor and a red button for stopping same. The movement in either direction of the car was controlled by a corresponding movement up or down on the rope. The lift enclosure was fitted with electrically interlocked doors but no car doors were fitted. Speed of the lift was 65 feet per minute.

Prior to the accident, deceased had taken a load of cartons to the basement in the lift. Witnesses stated that it was his intention to come straight back up again. There was nobody else in the basement and no one in the lift so there was no witness to the actual mishap. The first that was known was when the victim was seen from the floor above caught between the lift platform and a ground floor beam.

Investigations were hampered by the fact that nobody saw the accident happen. However it was found that the electrical interlock on the basement doors (there were two entrances at the basement level on the opposite sides of the shaft) were faulty. On one door the lock was permanently bridged, on the other lock was broken in the electrically made position. In effect the electrical interlocks were useless in this condition as a safeguard and the lift could be moved with the doors open. One of the most difficult features to explain was how the deceased came to be near or at the entrance where he was trapped when the control station was in the opposite corner of the lift. An attempt has been made to reconstruct the circumstances of the accident, taking this into account. The possible explanation given by the investigating officer is as follows—

> It is assumed the motor had been turned off and the victim entered the lift and started the motor, forgetting to close either one or both doors, and pulled the control rope. With the electrical locks in-operative the platform commenced to move upward. As the platform started to move he noticed that one or both of the landing doors were open and moved from his destination side near the control rope to the opposite side of the car. This appears to be the only reason for him to be on this side of the platform.
>
> It is further assumed that without stopping the lift he attempted to either close or latch the doors while the platform was moving upwards, by stepping off the slow moving platform to pull the doors. It appears possible that he was attempting to get up on the platform again when he was trapped.

It was also suggested at the inquest that the rope controlling the movement of the lift could have been operated by someone on another floor.

Irrespective of how the actual mishap occurred it should not have been possible, if the safety precautions as fitted, had been operative. Too much emphasis cannot be placed on the criminal folly of shorting out or bridging electrical interlocks in particular, or of removing or rendering useless any safety device fitted to machinery.

Section 6.

EXAMINATION OF ENGINE DRIVERS, CRANE DRIVERS AND BOILER ATTENDANTS.

During the year the Board of Examiners granted 136 Engine Drivers', 474 Crane Drivers' and 107 Boiler Attendants' Certificates of Competency.

Compared with 1965 these figures show increases of 22, 138 and 39 respectively in the numbers of certificates granted.

As with almost every other phase of the work of this Branch the expansion of the number of Engine Drivers' Certificates continues. For 1966 the figures show an overall increase of approximately 40% which when considered with expansions in the other duties of the Board Members, gives some idea of the increased pressure on them. The most spectacular increase in numbers is in Crane Drivers' & "A" Class Diesel Locomotive Drivers' certificates, which has been brought about to a large degree by heavy construction projects and the opening of two private railways for the transport of iron ore.

Section 7.

STAFF AND GENERAL.

This section for a number of years now has commenced with similar remarks deploring the lack of staff, particularly on the inspectorial side. This year is no exception. Requests for additional staff have been put forward on numerous occasions, sometimes granted in part but always due to the delay in implementation by the time extra staff commences duty the work load has outstripped the staff requested months previously. Nobody denies the industrial expansion taking place in Western Australia but the failure to realise that the work of this Branch increases in direct proportion is most disappointing. Particularly when everybody in the Branch is conscientiously trying to meet the demands of industry and the statutory requirements of the Inspection of Machinery Act. Unfortunately the results attained in the latter fall far short of what should be done.

The beginning of the year saw the appointment of two temporary inspectors which brought the Dept. up to allowable strength. This was followed by the return to Perth of Inspector Shaw and then the advertising of the position of Inspector-in-Charge, Kalgoorlie. There were no applications for this position. A second attempt resulted in one application. The applicant Mr. Downes was duly appointed. The reluctance of Inspectors to uproot themselves from Perth to go to Kalgoorlie where the position is only one grade higher is I think understandable. This considerable delay in filling this position meant that Acting Inspector-in-charge had to be furnished for Kalgoorlie.

During the year Mr. Jagger resigned from the Public Service and Mr. Harvey retired after many years of valuable service to the Branch. The two temporary inspectors having proved satisfactory were appointed to these two permanent items. The temporary items were then advertised.

The appeals of all members of the Inspectorial Staff against the re-classification of 1/1/63 were eventually heard during the year. One extra grade was granted to the Deputy Chief Inspector and the Senior Inspector of Machinery, but I regret the appeals of Inspector-in-Charge, Kalgoorlie, and the Inspectors of Machinery, were dismissed.

On the clerical side the submission of the previous year to make the Secretary to the Board of Examiners a position on its own was carried out. This has been more than justified. During the earlier part of the year it was necessary for many hours overtime to be worked by the Senior Clerk and the Registrar to overcome the backlag. There were several other changes of staff due to transfers and resignations. Towards the end of the year the Senior Clerk applied for and was successful in obtaining the position of Clerk of Courts at Esperance. His transfer to Crown Law Department is a loss to the Inspection of Machinery Branch. This year also saw the resignation of the assistant from the Boulder Office, after approximately ten years of most reliable service in the position.

There has been no relaxation of pressure on the staff during the year and as usual all have responded to the demands upon them. I wish to note my appreciation of their efforts.

Thanks also to the Police Department for their co-operation in the reporting of accidents and assistance given in investigations where we were associated.

In conclusion on behalf of all members of the Branch our appreciation of assistance given by yourself and all mines Dept. Officers when requested.

E. J. McManis,
Deputy Chief Inspector of Machinery.

RETURN No. 7.

Showing Serious Accidents Both Fatal and Non Fatal Which Occurred in Proclaimed Districts During the Year Ended 31/12/66.

"F" Denotes Fatal.

Industry	Pressure Vessels	Lifts	Mobile Cranes	Gantry Cranes	Tower Cranes	Winding Engines	Circular Saws	Bandsaws	Buzzers	Spindle Moulders	Belt Sanders	Abrasive Wheels	Belts and Shafting	Conveyors	Elevators	Lathes	Drilling Machines	Milling Machines	Metal Presses	Other Presses	Moulding Machines	Rolls	Guillotines	Punches and Shears	Mincers	Wrapping Machines	Pie Making Machinery	Washing Machines	Brick Making	Leather Splitter	Brushmaking	Teasing Machine	Opening Machine	Glass Making	Bottle Making	Totals per Industry
Woodworking and Furniture	....	....	1	....	....	....	5(1F)	....	3	1	1	....	....	....	....	....	....	....	....	....	....	....	1	....	....	....	....	....	....	....	....	1	....	....	....	13 (1F)
Metalwork and Engineering	....	....	3	4 (1F)	....	....	....	....	2	....	....	....	1	....	....	1	2	2	10	1	1	1	1	2	....	....	....	....	....	....	....	....	....	....	....	31 (1F)
Printing	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	1	1	....	....	....	....	....	....	....	....	....	....	....	....	2
Food and Drink Processes	....	....	....	....	....	....	1	1	....	....	....	....	....	2	1	....	....	....	....	1	....	1	....	....	3	1	1	1	....	....	....	....	....	....	....	13
Building Materials and Construction	1	....	2 (1F)	....	1	....	....	....	....	1	....	....	1	1	....	....	....	....	....	....	....	....	....	....	....	....	....	....	1	....	....	....	....	....	....	8 (1F)
Glass Manufacturing	....	....	....	....	....	....	1	....	....	....	....	....	....	....	....	....	....	....	....	....	....	1	....	....	....	....	....	....	....	....	....	....	....	1	1	4
Mining	....	....	1 (F)	....	....	3 (1F)	....	....	....	....	....	1	....	1	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	6 (2F)
Leather Processing	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	1	....	....	....	....	....	....	....	1	....	....	....	....	....	2
Paper and Fibre Box Manufacture	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	1	....	....	....	....	....	....	....	....	....	....	....	....	....	1
Brushmaking	....	....	....	....	....	....	....	1	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	2	....	....	....	....	3
Other Industries	2	1 (F)	1	....	....	....	1	....	....	....	....	....	....	1	....	....	....	....	....	....	....	1	....	....	....	....	....	....	....	....	....	....	1	....	....	8 (1F)
Totals per Machine	3	1	8	4	1	3	8	2	5	2	1	1	2	5	1	1	2	2	10	2	1	7	3	2	3	1	1	1	1	....	2	1	1	1	1	91

RETURN No. 7A.

Showing Number of Accidents Not Classed as "Serious" Under the Act Which Were Reported And Investigated During the Year Ended 31/12/66.

Industry	Pressure Vessels	Escalators	Hoists	Mobile Cranes	Circular Saws	Bandsaws	Buzzers	Spindle Moulders	Belt Sanders	Abrasive Wheels	Polishing Buff	Belts and Shafting	Conveyors	Lathes	Drilling Machine	Milling Machine	Metal Presses	Other Presses	Rolls	Printing Machines	Mincers	Washing Machines	Malt Rake	Hide Shaving	Totals per Industry
Woodworking	....	....	....	....	2	....	2	2	1	....	....	....	....	....	....	....	....	....	1	....	....	....	....	....	8
Metalworking	....	....	....	1	1	....	....	....	....	2	1	....	....	4	1	1	2	....	....	1	....	....	....	....	14
Printing	....	....	....	....	....	....	....	....	....	....	....	....	1	....	....	....	....	....	....	2	....	....	....	....	3
Food and Drink Processing	....	....	....	....	....	1	....	....	....	....	....	2	2	....	....	....	....	1	....	....	1	1	1	....	9
Building Materials and Construction	1	....	....	....	....	....	1	....	....	....	....	....	1	1	....	....	....	....	....	....	....	....	....	....	4
Glass Manufacturing	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	1	....	2	....	....	....	....	3
Leather Processing	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	1	1
Paper and Fibre Box Manufacturing	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	1	....	....	....	....	1
Other Industries	1	1	2	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	4
Total per Machine	2	1	2	1	3	1	3	2	1	2	1	2	4	5	1	1	2	2	1	6	1	1	1	1	47

RETURN No. 7B.

Accidents Involving Machinery *Not* Subject to the Provisions of the Act But Reported to and Investigated by the Department in Compliance With Section 50 During the Year Ended 31/12/66.

Industry	Milling	Drilling	Abrasive Wheels	Bending Machinery	Printing Machinery	Guillotine	Brush Cutter	Conveyor	Packing	Stapling	Totals per Industry
Metalworking	1	2	3	1	....	....	....	....	....	....	7
Printing	....	....	....	....	2	1	....	....	....	....	3
Brushmaking	....	....	....	....	....	....	1	....	....	....	1
Food and Drink Processing	....	....	....	....	....	....	....	1	1	1	3
Mining	....	....	1	....	....	....	....	....	....	....	1
Fertiliser	....	1	....	....	....	....	....	....	....	....	1
Plastics	....	....	....	....	....	....	....	1	....	....	1
Totals per Machine	1	3	4	1	2	1	1	2	1	1	17

RETURN No. 8.

Showing total of Engine Drivers' and Boiler Attendants' Certificates (all classes) granted in 1966 compared with 1965.

——			Numbers 1966	Granted 1965
Winding	Competency including Certificates issued under	Reg. 40 and Section 60 of the Act	6	7
First Class	" " " " "	Reg. 40 and 45 and Sections 60 and 63 of the Act	28	36
Second Class	" " " " "	Reg. 40 and Section 60 of the Act	10	12
Third Class	" " " " "	Reg. 40 and 45 and Sections 60 and 63 of the Act	14	11
Locomotive and Traction	" " " " "	Reg. 40 and Section 60 of the Act	8	....
Traction	" " " " "	Reg. 40 and Section 60 of the Act	1	....
Internal Combustion	" " " " "	Reg. 40 and Section 60 of the Act	45	42
Crane and Hoist	" " " " "	Reg. 40 and Section 60 of the Act	474	336
Boiler Attendant	" " " " "	Reg. 50 and Section 60 of the Act	107	68
Diesel Loco.—				
Class A	" " " " "	Reg. 40 and Sections 53 and 56 of the Act	24	4
Class B	" " " " "	Reg. 40 and Sections 53 and 56 of the Act	....	2
Interim Certificates	....	Section 61	4	3
Copies	....	....	18	11
			739	532

RETURN No. 9.

Revenue and Expenditure for year ended 31st December, 1966 and comparison with preceding year.

——	Revenue 1966	Revenue 1965
	$	$
Fees for Boiler Inspections	13,641·89	13,050·95
Fees for Machinery Inspections	20,486·32	17,954·22
Fees from Engine Drivers	2,724·67	2,161·10
Incidentals	706·06	488·59
Total	$37,558·94	$33,654·86

Increase in Revenue compared with 1965—$3,904·08

——	Expenditure 1966	Expenditure 1965
	$	$
Salaries	106,399·63	88,421·09
Incidentals	19,728·89	17,950·03
Engine Drivers' Examinations	1,050·60	344·91
Totals	$127,179·12	$106,716·03

Increase in Expenditure compared with 1965—$20,463·09

RETURN No. 10.

Showing Distances Travelled, Number Inspections Made and Average Miles Travelled for Inspections for the year ended 31/12/66.

——	Road Miles	Air Miles	Rail Miles	Water Miles	Collective Mileage all Transport Services	Number of Inspections	Average Miles per Inspection
Districts operated from Perth	131,524	2,090	*Nil*	*Nil*	133,614	37,248	3·58
Comparison with 1965	Inc. 8,440	Inc. 390	*Nil*	*Nil*	Inc. 8,830	Inc. 4,406	Dec. 0·22
Districts operated from Boulder	14,636	*Nil*	*Nil*	*Nil*	14,636	4,232	3·458
Comparison with 1965	Inc. 101	*Nil*	*Nil*	*Nil*	Inc. 101	Dec. 106	Inc. 0·108
Totals	146,160	2,090	*Nil*	*Nil*	148,250	41,480	3·57
Comparison with 1965	Inc. 8,541	Inc. 390	*Nil*	*Nil*	Inc. 8,931	Inc. 4,300	Dec. 0·18

Note Abbreviations :—Inc. = Increase ; Dec. = Decrease.

Average Miles per inspection all districts, 1966	3·57
Average Miles per inspection all districts, 1965	3·75
Increase per inspection compared with 1965	Inc. 0·18
Decrease	Dec.

RETURN No. 11.
Engine Drivers' and Boiler Attendants' Board Matters.
1966

Examinations in—

Perth, 4.	South West, 3.	North West Ports, 1.
Kalgoorlie, 2.	Esperance, 2.	Morawa, 1.
Bunbury, 1.	Geraldton, 2.	

Special Examinations, 90.

Examinations were held at all advertised centres.

86 days on actual examinations by travelling Board.
50 days spent in Perth dealing with applications for competency certificates, examination papers and enquiries, etc.
85 days spent in travelling and looking into matters connected with engine drivers and boiler attendants.
764 applications received.
739 certificates granted.
Revenue $2,724·67

DIVISION VII

Government Chemical Laboratories Annual Report—1966

Under Secretary for Mines:

I have the honour to present to the Honourable Minister for Mines a summarised Annual Report on the operations of the Government Chemical Laboratories for the year ended 31st December, 1966.

Administration.

The Laboratories consist of 6 Divisions, a Physicist and Pyrometry Section, a library and a central office all under the control of the Director (Government Mineralogist, Analyst and Chemist) as follows:—

Director—L. W. Samuel, B.Sc., Ph.D., M.A.I.A.S., M.R.S.H., M.Inst.F., F.R.A.C.I., F.R.I.C.

Deputy Director—R. C. Gorman, B.Sc., M.A.I.A.S., A.R.A.C.I.

Agriculture and Water Supply Division—H. C. Hughes, B.Sc., A.R.A.C.I., Divisional Chief.

Engineering Chemistry Division—S. Uusna, Dr. Ing., M.Aust.I.M.M., A.M.I.E.(Aust.), M. Inst.F., Divisional Chief.

Foods, Drugs, Toxicology and Industrial Hygiene Division—N. R. Houghton, B.Sc., A.R.A.C.I., Divisional Chief.

Fuel Technology Division—R. P. Donnelly, M.A., B.Sc., C.Eng., M.I.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.S.P.I., Divisional Chief.

Mineralogy, Mineral Technology and Geo-Chemistry Division—G. H. Payne, M.Sc., A.W.A.S.M., A.R.A.C.I., Dvisional Chief.

Physics and Pyrometry Section—N. L. Marsh, B.Sc.

Librarian—Miss J. E. Maughan, B.A.

Office—Miss D. E. Henderson, Senior Clerk.

At 31st December, 1966, the staff of the Laboratories numbered 110 being

Professional	61
Cadets	6
General	32
Clerical	8
Wages	3

This is an increase in staff numbers of nearly 20 per cent compared with 1965 and has been permitted by the completion of the extensions to our buildings. This increase occurred late in 1966 and as yet has had no appreciable effect on the accumulation of samples to be examined.

The close association of these Laboratories with other Government Departments, and with kindred associations was maintained during 1966 and various members of the staff are members of the following Committees:—

Air Pollution Council

Applied Science Advisory Committee

Australian Coal Industry Research Laboratories Limited—Board of Management

Commonwealth Scientific and Industrial Research Organisation State Committee

Fluoridation of Public Water Supplies Advisory Committee

Food and Drugs Advisory Committee

National Association of Testing Authorities State Committee

National Coal Research Advisory Committee

Oils Committee of the Government Tender Board

Paints Advisory Committee of the Government Tender Board

Pesticides Registration Committee

Phytochemical and Toxic Plants Committee

Poisons Advisory Committee

Rivers and Waters Technical Advisory Committee

Scientific Advisory Committee under the Clean Air Act

Swan River Conservation Board

Veterinary Medicines Advisory Committee

Water Purity Advisory Committee.

Most of these Committees are very active and meet regularly and occupy considerable time of the officers concerned, not only for meetings, but also for inspections, preparation of information and analyses of samples.

The Air Pollution Control Council and the Scientific Advisory Committee under the Clean Air Act had numerous meetings during the year to formulate Regulations under the Act and this task is now nearing completion.

Dr. Uusna and Mr. Donnelly have continued regular attendance at meetings of the National Coal Research Advisory Committee and the Board of Management of the Australian Coal Industry Research Laboratories Ltd. respectively.

The Pesticides Registration Committee dealt with 108 applications for registration of new pesticide formulations. The total number of applications considered by this Committee to 31st December, 1966, is 1897. A matter of great concern to this Committee is the poisonous nature of many of the newer pesticides, especially as many of them can be absorbed through the skin. The Committee has maintained its past policy of on occasions refusing registration of a pesticide as being too hazardous to health; placing an upper limit on the concentration of active ingredient in the formulation to be distributed; or has restricted distribution to commercial pest exterminators. For the Swan River Conservation Board we analysed 110 samples of river water and 17 samples of effluents being discharged into the river. The Veterinary Medicines Advisory Committee dealt with 917 applications, being 769 renewals, 109 new registrations, 3 changes of formula or claim, 30 deferred, 5 not required to be registered and 1 rejection.

In addition to the above Committees the Director was very much occupied during the year with the amendments, Sections 32A, 32B, 32C and 32D, to the Traffic Act providing for the use of the Breathalyzer as well as blood samples for determining the concentration of alcohol in the blood of drivers. The Director is responsible not only for accrediting analysts for the blood samples but also the operators of the Breathalyzer for breath tests and is the expert witness on the Breathalyzer for Court purposes. In January the Director accompanied police officers to Melbourne to obtain the benefit of the experience of police staff in that city. The amendments came into operation on 1st October, 1966, and have operated smoothly.

Equipment.

Another Atomic Absorption Spectrophotometer with air-acetylene and nitrous oxide-acetylene burners was obtained and also a GKN micro-hardness tester.

Accommodation.

It is very pleasing to record that the extensions to the Adelaide Terrace buildings of these Laboratories are now complete and occupied. These extensions approximately double the laboratory working space in each of the three larger Divisions and also double the Library and Refectory area. Even so, the increase in professional literature is so great that it is necessary to cull heavily the material on the Library shelves. Older and less frequently used books and journals have been removed to the store-room where they are still available for reference.

Plans have been drawn and the tender let for extensions to our Engineering Chemistry Division at Bentley and construction should be completed in 1967.

General.

The total number of registrations for 1966 was 4,045 an increase of some 10 per cent over the 3,616 registrations for 1965. The number of samples received in 1966 was 15,522 an increase of some 5 per cent over the 14,816 received in 1965.

The increase in sample numbers, as indicating the increase in work undertaken in these Laboratories, during the past five years is shown in the following Table. The increase is some 45 per cent.

Year	Samples received
1962	10,658
1963	11,421
1964	12,962
1965	14,816
1966	15,522

The increase in our accommodation and staff has enabled us to cope with the increase in samples from 1965 to 1966 but has not yet affected appreciably the backlog of work in hand. At the end of 1966 the number of samples received but not reported was 3,234 compared with 3,569 at the end of 1965.

The number of registrations and of samples does give some measure of our activities but does not completely describe our work. A major factor in this is the variation in the amount of work associated with different samples. Also it is not possible to give a statistical account of the time and effort devoted to the various Committees mentioned; to advisory work for Government Departments, industrial firms and the general public; attendance at Courts; visits to factories and so on.

The samples received during 1966 were allocated to the various Divisions of these Laboratories according to the specialised work undertaken by each Division, 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 ability and experience of different specialists. Such samples are not usually registered twice but do show in the totals of samples received by the Divisions so the total in Table 1 is greater than the total of samples quoted earlier in this report. This co-operation between and mutual assistance of Divisions helps to foster the policy that we are one Government Chemical Laboratories not 6 separate Divisions.

Discussion and interchange of ideas between Divisions is encouraged since the problems received by one Division may be helped by, indeed may rely on, the specialist in another Division. To assist in this we introduced in 1965 talks by senior chemists to groups of staff from other Divisions, talks on the work done, the facilities available and the capacity of those facilities.

Fees were charged for work undertaken for some State Government Departments, Government Instrumentalities, for Commonwealth Government Departments, Hospitals, Milk Board, private firms and the general public, but the greater part of our work is done without charge for other State Government Departments, together with an appreciable amount of free mineral identification and assay to assist prospectors.

TABLE 1

Source and Allocation of Samples Received During 1966

Source	Division							Total
	Agriculture	Engineering Chemistry	Food and Drug	Fuel Technology	Industrial Chemistry	Mineralogy	Physicist and Pyrometry Officer	
State—								
Agriculture Department	5,180	....	994	....	....	....	....	6,174
Crown Law Department	....	....	1	....	....	....	....	1
Departmental	46	....	3	78	61	300	1	489
Fisheries and Fauna Department	65	....	....	....	....	1	....	66
Hospitals	3	....	110	2	....	....	....	115
Industrial Development Department	....	....	1	....	4	1	....	6
Labour Department	....	....	26	....	....	....	....	26
Lands and Surveys Department	6	....	....	....	....	30	....	36
Main Roads Board	....	....	....	....	....	30	....	30
Medical Department	2	....	2	....	....	....	....	4
Metropolitan Water Supply	500	....	3	2	1	15	....	521
Milk Board	....	....	679	....	....	....	....	679
Mines Department	416	....	26	2	3	483	....	930
Native Welfare Department	1	....	....	....	....	10	....	11
Police Department	21	....	1,289	....	....	....	....	1,310
Public Health Department	25	....	301	7	....	10	....	343
Public Works Department	448	....	84	12	31	37	18	630
State Housing Commission	....	....	....	1	....	....	....	1
Swan River Conservation Board	....	....	127	....	....	....	....	127
Treasury Department	2	....	94	....	....	....	....	96
University	11	....	....	....	....	....	3	14
Western Australian Government Railways	....	....	3	....	....	....	....	3
Zoological Gardens Board	1	....	....	....	....	....	....	1
Commonwealth—								
Air Department	2	....	30	....	7	....	....	39
Customs Department	1	....	....	....	....	....	....	1
Navy Department	....	....	1	....	....	....	....	1
Postmaster General's Department	3	....	2	....	....	4	....	9
Works Department	....	....	....	....	....	7	....	7
Public—								
Free	2	....	5	....	....	1,757	3	1,767
Pay	869	13	219	70	15	1,154	9	2,349
United States Navy	8	....	....	....	....	....	....	8
	7,612	13	4,000	174	122	3,839	34	15,794

The summarised reports of the individual Divisions which follow show the very wide range of subjects dealt with by these Laboratories. Comparing 1966 with 1965 there were some marked alterations in the numbers of various types of samples received. These were:—

	1965	1966
Marked increase—		
Apple	174	410
Gold	378	521
Milk	588	865
Mineral identification	606	937
Nickel	—	179
Pasture	130	854
Plants—toxic	53	162
Soils	503	784
Water	1702	2304
Wheat	1044	1756
Marked decrease—		
Arsenic (mineralogy)	2077	409
Clover	941	535
Fertiliser	205	68
Grass	288	58
Iron	232	139
Lead	101	38
Linseed	565	17
Oat	209	20
Pesticides	337	132

In addition to the Conferences attended and the Talks given that are referred to in the individual Divisional Reports the Deputy Director, Mr. R. C. Gorman gave the following Talks,

"A review of corrosion of copper tubing", Presidental Address to the Western Australian Branch of the Australian Corrosion Association.

"Treating of cooling water for air-conditioning" to the Jubilee Conference of the Australian Institute of Refrigeration, Air Conditioning and Heating and to the Second Annual Seminar of the same Institute in Adelaide.

L. W. SAMUEL,
Director.

AGRICULTURE AND WATER SUPPLY DIVISION.

During 1966 we were at last able to fully occupy the new wing of the Division, the last of the services being completed in October.

In March, Mr. George Dean who had served the Laboratories and the Division since 1934, retired after 32 years thus severing the last link with pre-War days and the old laboratories. Miss Wilson and Mr. Weir, officers with long experience, were promoted to Grade II positions, and the resultant vacancies together with two further positions for base grade chemists and two for technicians were filled between October and December. The services of two officers borrowed from other Divisions came to an end, firstly by the resignation of Mr. Giumelli and secondly the return of Mr. Douglas to the Industrial Chemical Division. To both these officers and their Divisions we were grateful for their ready help.

The output of samples for the year at 7,942 was in excess of receivals at 7,612, for the first time since 1962. These receivals were an increase of 22 per cent over 1965 and represent half of all samples received in the Laboratories for the year. This shows the additional work involved in this Division in sample receival and preparation, records and reports, apparatus handling and analysis. That good results were achieved is attributable firstly to co-operation from the staff, which numbered 19 for most of the period, and secondly the use made of the improved facilities and instrumentation.

The most significant increases, in Cereals and Soils at about 50 per cent of the samples received reflected work being undertaken to anticipate changing fertiliser practice which is likely to result from the new products which will be available from the expanded fertiliser industry at Kwinana. Horticultural samples actually doubled but the numbers involved were not so great in this category. Decreased receivals were in the fertilisers, where less work was necessary on trace element additions, and under Miscellaneous, there being no receivals of linseed or safflower.

The number, type and source of the samples received in 1966 are listed in Table 2.

TABLE 2

Agriculture and Water Supply Division

	Agriculture Department	Departmental	Fisheries Department	Metropolitan Water Supply	Mines Department	Police Department	Public	Public Health Department	Public Works Department	University	Other, State Departments	Other	Total
Animal—													
Faeces	13	....	....	....	....	....	....	....	....	....	....	....	13
Kidney	40	....	....	....	....	....	....	....	....	....	....	....	40
Liver	104	....	....	....	....	....	....	....	....	....	....	....	104
Various	3	....	....	....	....	....	....	....	....	....	....	....	3
Cereal—													
Oat Hay	20	....	....	....	....	....	....	....	....	....	....	....	20
Wheat—													
Flour	6	....	....	....	....	....	....	....	....	....	....	1	7
Grain	371	....	....	....	....	....	....	....	....	....	....	....	371
Leaves	16	....	....	....	....	....	....	....	....	....	....	....	16
Straw	39	....	....	....	....	....	....	....	....	....	....	....	39
Tops	1,246	....	....	....	....	....	....	....	....	....	....	....	1,246
Tops and Roots	64	....	....	....	....	....	....	....	....	....	....	....	64
Various	13	....	....	....	....	....	....	....	....	....	....	....	13
Various	7	....	....	....	....	....	....	....	....	....	....	....	7
Fertilisers—													
Act	29	....	....	....	....	....	....	....	....	....	....	....	29
Fertilisers	22	....	....	....	....	....	....	....	....	....	....	....	22
Various	4	....	....	....	....	....	13	....	....	....	....	....	17
Horticulture—													
Apple—													
Leaves	275	....	....	....	....	....	....	....	....	....	....	....	275
Tree parts	120	....	....	....	....	....	....	....	....	....	....	....	120
Orange leaves	106	....	....	....	....	....	....	....	....	....	....	....	106
Pear leaves	16	....	....	....	....	....	....	....	....	....	....	....	16
Various	56	....	....	....	....	....	....	....	....	....	....	....	56
Miscellaneous—													
Blood	....	....	....	....	....	12	....	....	....	....	....	....	12
Cotton seeds	84	....	....	....	....	....	....	....	....	....	....	....	84
Deposits and scales	1	....	....	....	1	....	2	2	9	1	1	4	21
Various	3	....	....	3	....	....	21	19	7	2	2	2	59
Pastures and Fodders—													
Clover	535	....	....	....	....	....	....	....	....	....	....	....	535
Clover and grass	51	....	....	....	....	....	....	....	....	....	....	....	51
Grass	58	....	....	....	....	....	....	....	....	....	....	....	58
Grass and herbs	192	....	....	....	....	....	....	....	....	....	....	....	192
Pasture	854	....	....	....	....	....	10	....	....	....	....	....	864
Various	25	2	....	....	....	....	37	....	....	....	....	....	64
Soil	765	....	....	....	....	....	19	....	....	....	....	....	784
Water	42	44	65	497	415	....	769	13	432	8	9	10	2,304
Total	5,180	46	65	500	416	12	871	34	448	11	12	17	7,612

Soils.

1. Phosphate.—(a) Fractionation of soil phosphorus was carried out for a range of glasshouse and field trials investigating the effects of levels of superphosphate on the maintenance of pasture growth. Future testing it is hoped will show which forms of phosphate are more available and which treatments may render available some of the fixed forms of phosphorus. Such determinations may also be a guide to work on soil tests for deciding fertiliser requirements.

(b) An experiment on Caitup Sand at Esperance in which rates of super from 0.5 to 4 cwt. per acre per year had been applied in four successive years to Bacchus Marsh clover, was to check a previous finding with Fleming Gravelly Sand, that phosphorus although moving down the profile is not lost completely to the plants. Comparison of the treated soils showed that even at the greatest rate, phosphorus had not moved beyond 14 in., including the surface 2 in., a transition zone 2-4 in., and pale grey sand above the gravel found below 14 in. The organic component of the soil phosphorus showed no increase with treatment but since it constituted ⅓ to ½ of the total phosphorus except at the maximum treatment its release by mineralisation after cultivation could be significant for subsequent crop growth.

2. Irrigation.—(a) Chemical examination of profiles of Cununurra Clay, taken from areas of Kimberley Research Station, which had been irrigated over a period of 10 years revealed differences induced by irrigation practices.

The profiles examined were:

(i) Virgin soil—unirrigated.

(ii) Flood irrigated—under rice, 42 acre ft. per 10 yr.

(iii) Furrow irrigated—under safflower, 26 ac/ft per 10 year.

These were sampled at 1 ft. intervals to a depth of 8 ft. Water soluble chloride confirmed the view that furrow irrigation caused a build up of chloride below 4 ft. However the water soluble cations did not show a corresponding marked increase.

Exchangeable sodium increased under both irrigation methods to about the same degree to the four foot level, and at deeper levels more markedly under the rice with the greater total application, the furrow irrigated being little higher at depth than the virgin soils. Similar changes in E.S.P. (exchangeable sodium percentage) indicated that exchange between sodium ions in the soil solution and the calcium and magnesium of the soil colloids was proceeding at the same rate if the soil was thoroughly wetted, irrespective of the total amount of water applied for irrigation.

The figure of 35 per cent for E.S.P. below 4 ft. after 10 years of irrigation totalling 42 acre ft. suggests that the subsoil could become dangerously close to the limits of 45-50 per cent E.S.P., believed desirable for irrigated soils.

It is pleasing that soils of such low inherent permeability have not shown signs of poor drainage at this stage. It is fortunate that the irrigation water is of excellent quality and that there is abundant calcium in the exchange complex and also present as calcium carbonate nodules in these soils.

(b) A similar study at Camballin showed the effects of 5 years of flood irrigation for rice crops.

The most obvious effect was the reduction in water soluble salts in the irrigated soil. The removal of chloride was particularly apparent in the top four feet of soil and quite marked to a depth of 6 ft. All the water soluble cations showed a general leaching of salts but there had been an increase in exchangeable sodium under irrigation.

The highest figure for E.S.P. was about 25 per cent, occurring at 3 ft. and below. However the virgin soil also had an E.S.P. of over 15 per cent below 1 ft. and drainage had not been impeded, although 15 per cent E.S.P. is commonly accepted as the level above which drainage problems may be experienced. It seems that in this soil with a large percentage of calcium in the exchange complex, permeability will be only slightly reduced under present irrigation practice.

(c) A series of samples of Mantinea Clay soils from Carlton Plains were tested for their exchangeable sodium percentage at the 1 and 3 ft. depths. The 1 ft. samples varied from 2 to 15 per cent and 3 ft. samples from 5 to 33 per cent E.S.P.

(d) 14 samples of soil from Carnarvon, where poor bean growth resembled the results of high soluble salts or high exchangeable sodium or potassium but could not be correlated with these factors, were tested for boron in the saturation extracts. While the levels of boron in 11 of these could be considered marginal at 0.7 to 1.1 parts per million they also failed to relate to the growth of beans on the sites which they represented.

3. Nitrogen.—(a) The 1965 and 1966 samples of soil from the Long-term Ley Rotation Experiment at Wongan Hills Research Station, were analysed for total nitrogen. Nitrogen is being used as the indicator of the effects of clover on soil fertility, and the effect which this anticipated improvement will have on the yield and quality of subsequent grain crops will be measured in the future. This is the tenth year from the commencement of the experiment designed to replicate in successive years to offset the effects of seasonal conditions. The first of the series has now had a history of fallow, 2 successive wheat crops and 7 subsequent years under grazed clover. The graphically presented preliminary results for the means, with the extreme results shown as an indication of the extent of seasonal effect, indicate that nitrogen content has been approximately doubled during the period of the experiment, Figure 1.

(b) 28 soils from pot experiments showed that nitrogen fertiliser applied to sawdust mulch—in favour for orchard use—either as ammonium sulphate at 1,300 lb. per acre or the equivalent as sodium nitrate, was entirely retained in 3 inches of mulch.

4. Trace Elements.—Total copper and copper extractable by 0.5 M E.D.T.A., were determined on soils from many sites where grain yield responses had been obtained, and also from pasture experiments.

From Esperance Downs Research Station the residual value of copper sulphate, first applied 12 years previously, and in some plots at 3 or 6 year intervals subsequently, totalling variously from 5 to 50 lb per acre, was shown to depend on satisfying an initial fixation of copper of the order of 1 part per million. Once this was satisfied, the so called available copper or E.D.T.A. extractable, increased directly with rate of application.

The clover cut in both July and September had an adequate content of copper even without the use of copper fertiliser so that the benefit of further addition was hard to assess. However the maximum level of copper was obtained for the July cut and was from the treatments receiving top dressings in the year of sampling, but even 5 lb per acre applied 12 years previously produced a 50 per cent increase in copper concentration.

5. Organic Carbon.—(a) 40 samples representing 4 different cultivation practices tried at Wongan Hills, revealed that the organic carbon content was highest in the plots which had been scarified at 2 m.p.hr. and sown with the combine at 4 m.p.hr. in 3 successive seasons. This and other results showed that carbon content related to stable aggregation and confirmed structure measurements which indicated that increased speed of cultivation produced a poorer soil structure, and that the scarifier was less damaging than the broad set disc plough.

(b) At South Quairading, on an area of salmon gum country carrying Wimmera rye grass sown in 1958 and which had received various rates of either sulphate of ammonia or calcium ammonium nitrate, wheat was sown in 1965. Half received additional sulphate of ammonia at 106 lb per acre. Yields indicated that past application of nitrogen had no beneficial effect, but that the 1965 application gave a small yield increase.

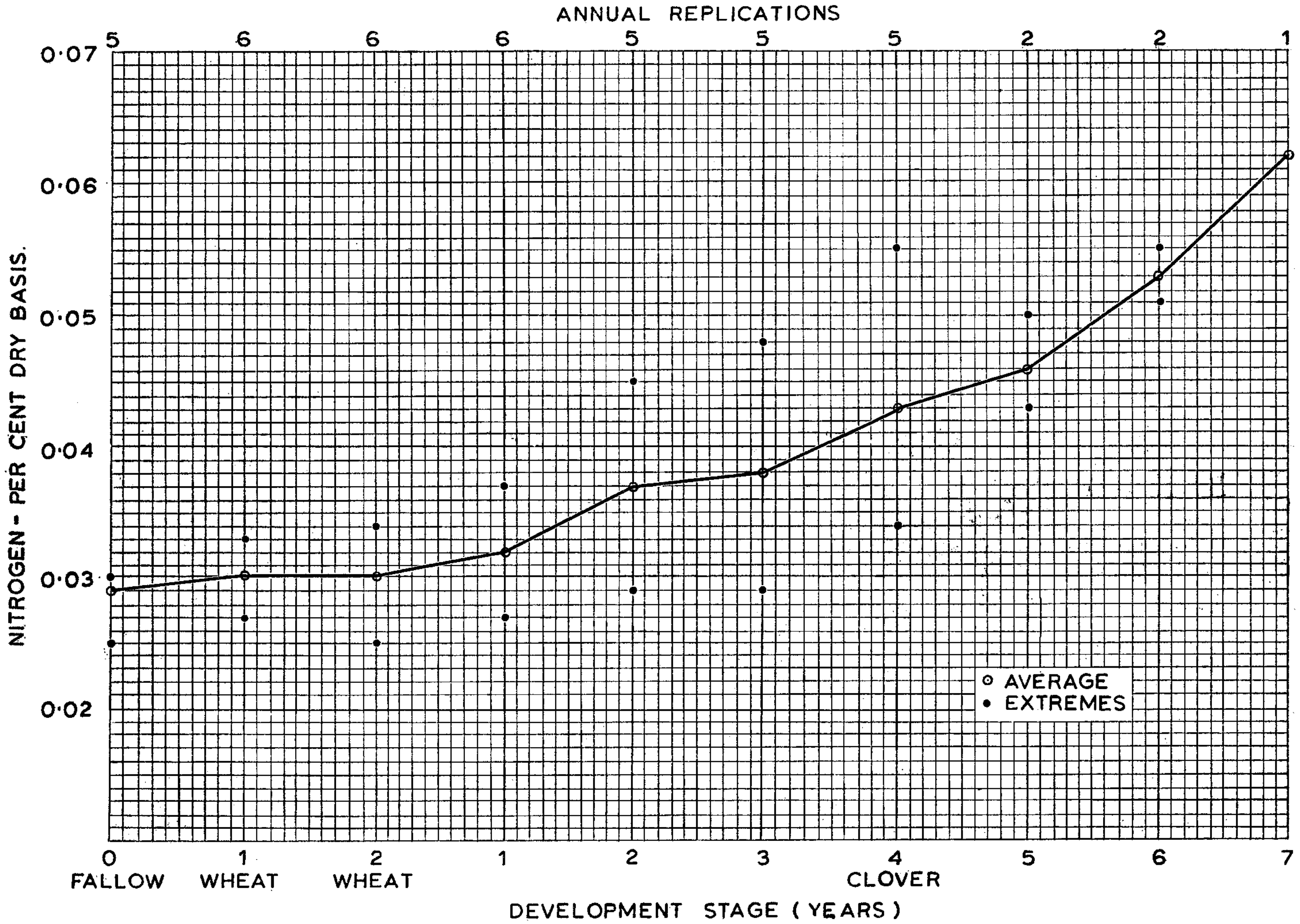


FIGURE 1.

LONG TERM LEY ROTATION EXPERIMENT, WONGAN HILLS RESEARCH STATION

Work of Heard (J. Agr. Sc. 1965) had shown that neither the weight of macro-organic matter (greater than 0.25 mm) nor the weight of the nitrogen it contained, affected crop yield. However the per cent of nitrogen in the macro-organic matter was positively correlated with the grain yield of the first wheat crop. It was deduced from this that the N/C, nitrogen-organic carbon ratio, of the leached greater than 0.25 mm soil fraction should also be positively correlated and this was confirmed by the results.

Fertilisers.

1. Fertilisers Act.—29 samples were examined under the Act, compared with 77 in the previous year. Of them, 3 were deficient in water soluble phosphate, 2 in copper and 1 in zinc.

2. Rock phosphates which were to be used in preparation of stock food supplements were again tested for fluoride. It was confirmed that Christmas Island rock contained 2.4 per cent fluoride, but although higher than desirable, this is still the best available source of rock phosphate for this purpose.

3. Flue dust from a cement works, reported as a rich source of potassium in the 1965 Annual Report, contained trace elements only of the same order as are found in plant materials and thus the trace element content was of no additional fertiliser value.

4. Among a variety of other samples were superphosphates with various additives to confirm that delivered material was as ordered, limesands for neutralising value or use in pelletting clover seed, and guano, which is not economic to work unless for use on nearby areas.

Pastures, Fodders and Stock Foods.

1. Feeding Stuffs Act.—9 samples were analysed of which one was confirmed as deficient in protein. Dried milk products were found to differ from their registrations only if tested by methods intended for application to cereal, pasture and meat meal products and not when analysed by methods appropriate to themselves. Alterations to the Certificate of Analysis were suggested.

2. Clovers and clover pastures.—(a) Rates of Stocking: (i) In the experiment at Mt. Barker which in 1964 showed for the clover component improved contents of protein, phosphorus and sulphur and decreased fibre with increasing stocking rate, the 1965 results, on samples taken midwinter, spring and summer, presented a different picture.

4 sheep to the acre did not produce any significant variation in the nutrient contents compared with ungrazed plots; 5 and 6 sheep per acre tended to increase protein and phosphorus contents but made no difference to either sulphur or fibre. At each stocking rate the use of 3 cwt. per acre of superphosphate made no difference to any nutrient level by comparison with 2 cwt. per acre.

(ii) The parallel experiment at Avondale showed that the protein in summer cuts was increased by 1.5 per cent by grazing but was not altered further by increasing stocking rate from 2 to 4. At Mt. Barker a further 1.5 per cent increase had been obtained by going from 5 to 6 sheep per acre. Phosphate also increased with grazing but not by increased stocking rate, and fibre decreased by grazing but not by increased stocking rate.

Thus nutrient content variations do not alter uniformly at the two sites and are not reproducible in successive seasons.

(b) Fertiliser Experiments.—(i) Clover was grown in a glasshouse experiment on the use of calcined rock phosphate with and without added gypsum, and superphosphate at rates equivalent to 80, 120 and 160 lb per acre super. On Wongan Loamy Sand no increased uptake of phosphorus was obtained in the first year even at the maximum rate of rock phosphate. Phosphorus was as readily taken up from the superphosphate in its usual form as when powdered. A similar experiment on Badgingarra Gravelly Sand confirmed this finding although the levels of phosphorus in the clover on this soil with super application were appreciably higher.

By the second cut a slight improvement was apparent from the rock phosphate on the Wongan soil and a more significant increase on the Badgingarra soil, but when cut at seeding no effect was seen in samples from the Wongan soil even for superphosphate treatment, although the samples on Badgingarra Gravelly Sand showed some increase from use of superphosphate.

(ii) Samples from "Rate and Time of Application of Potash" trials showed again the benefit of splitting applications between autumn and spring. Additional information was obtained from a trial on Plantagenet peaty sand at Torbay, typical of deficient swampy country around the south coast. Here samples of clover cut in July were showing improved potassium uptake as the result of fertiliser added in the spring of the previous year.

(iii) At the end of an eight year cycle on mixed pasture at Manjimup, total rates of super of 1792 and 3584 lb per acre applied in annual and biennial increments or as an initial treatment, were compared with basic super, 50/50 lime superphosphate, Rhenania phosphate, rock phosphate and superphosphate with an initial 2 ton dressing of limestone, all at equivalent phosphate rates.

All treatments except the rock phosphate revealed that the smaller annual dressings reached the same level of 0.20 $\pm$ 0.01 per cent dry basis of phosphorus in the clover, and double the rate resulted in an increase to only 0.25 per cent whether by annual or biennial application. Only in the instance of the 50/50 lime superphosphate did the single and heavier dressing result in the same phosphorus content as the lighter annual dressing.

In the case of rock phosphate the phosphorus levels obtained by annual or biennial application, were equivalent only to the level reached from using the other phosphates as an initial application.

The grass component of all pastures showed a similar story at only marginally lower levels of phosphorus.

(c) Trace Elements. (i) A considerable amount of work was done during the year with molybdenum treatments.

Geraldton sub-clover grown at Merredin had shown increased nodulation and growth when molybdenum was applied with the superphosphate, but molybdenum mixed with the lime pelletted seed reduced nodulation and dry matter production, the effect being more severe with higher rates. It was found that both adding the molybdate with the superphosphate, and inoculation had resulted in reduced concentration of molybdenum in the clover, and also reduced the concentration of both nitrogen and copper.

Sub-clover from Merredin compared uptake from roasted molybdenite and sodium molybdate and the effects on the pasture as a feeding stuff. At all rates of application, from the equivalent of ½ to 6 oz. per acre of molybdenum trioxide, the uptake was the same from either source. The equivalent of ½ oz. per acre was sufficient to ensure maximum protein nitrogen, with 1.5 ppm Mo. The use of higher rates increased the molybdenum content to 5-9 ppm, while copper content was 5-6 ppm and inorganic sulphate 0.3-0.5 per cent.

When clover at Forrestania which without treatment was already at 0.3 ppm dry basis molybdenum, received roasted molydenite at 3, 6 and 12 oz. per acre the molybdenum content rose to 6, 12 and 19 ppm respectively. There was evidence of decreased molybdenum concentration as the result of the use of superphosphate, and protein nitrogen related to superphosphate treatment rather than to molybdenum content.

At a Woogenellup site, copper applied in various forms 4 years prior to cutting showed that the carbonate and oxide if ground to less than 50 mesh B.S.S. were as readily available as copper sulphate. Sulphide ore however required grinding to less than 200 mesh B.S.S. for the same result.

Residual copper trials at Bramley showed in summer samples after 3 years, that as usual the legumes, whether introduced or native had greater capacity for taking up copper when it was present at better than deficient levels. However the copper contents of the 2½ lb per acre copper sulphate treated pastures were sub-normal, and 7½ lb per acre only produced normal levels.

(iii) Intense reddening of clover on a clay soil at Waterloo was attributed either to boron deficiency, or an imbalance of cations. Since all samples contained the same amount of boron, the fact that the most severe symptoms were shown by plants at 0.7 per cent calcium with 1.4 per cent potassium and healthy plants had 1.6 per cent calcium and 0.8 per cent potassium may have been significant.

3. Miscellaneous Pastures and Feeding Stuffs.—(a) Selenium determinations were made either as part of a survey in a specific area where White Muscle Disease had been diagnosed or as an investigation of plants known to have the ability to accumulate selenium.

In general, samples of pastures from diagnosed deficiency areas contained 0.03 ppm Se or less but from a property at Deeside the pastures contained 0.2 to 0.8 ppm, which are comparatively high figures.

Samples of note among the accumulator plants were *Neptunia monosperma* from Denham Station 0.4 ppm, and *Tribulus terrestris* samples from Merredin and the Ord River, which contained 1.1 and 4.5 ppm respectively.

(b) Sheep grazing pastures at Bramley Research Station which were dominant in either strains of soft brome or wimmera rye grass were losing weight in September and October and a number died. The most affected were those on the wimmera rye which was very grass dominant. Indications from serum and vitamin B12 levels, were a severe cobalt deficiency although the area had received 8 oz. per acre of cobalt sulphate 4 years previously. All grass samples were found to contain 0.04 ppm or less of cobalt, and also 0.02 ppm or less of selenium

(c) Residual effects of cobalt fertiliser were further shown as negligible at Bramley after only 2 or 3 years when cobalt sulphate at 1, 3, 9 and 18 oz. per acre failed to show any residual benefit in the grass component of the pasture although weeds had an improved uptake at the higher rates.

At Esperance, in the year of application of 1, 3 and 9 oz. per acre cobalt sulphate each level showed increased uptake in both grass and weeds, but the effect was more pronounced in August cut samples than in October cuts.

(d) Samples of pasture from Manjimup on which copper deficiency was suspect, were found to contain approximately 17 ppm copper, which was more consistent with the history of having received 10 lb per acre copper sulphate in two successive years 20 years previously, followed by 7½ lb per acre for three further years. Thus, although no copper had been applied recently, the massive treatment was proving more than adequate 15 years later.

(e) Puccinellia, a salt tolerant grass being used in the reclamation of salt affected land, was shown as having some value as a feeding stuff with protein content of up to 13.8 per cent, although the ash as might be expected was about 10 per cent.

Another species being tried for salt land regeneration was *Tamarix aphyllia,* a small tree with fir-tree like foliage. This foliage contained 13.4 per cent protein and could also be a good supplementary feed in drought, if the trees will stand summer pruning.

Sudan grass, sudax and sorghum almum from Mt. Hart contained protein of 5.6, 5.4 and 4.8 per cent respectively. This was the first sample of sudax, a recent introduction received here.

Cereals.

1. Oats.—(a) Tops and roots from Esperance were either untreated or had received copper and zinc either alone or in combination 6 years previously. Levels of copper in the tops were only of the order 2-3 ppm and the residual benefit very slight, and zinc, 10 and 12 ppm in untreated oats was only 12 and 17 ppm with treatment.

(b) On another Esperance experiment urea, 50 to 100 lb per acre, was applied either at seeding or 3 weeks later to plants sown on one of three dates at 3 week intervals. The site had previously been under clover. The times of sampling in August were 11, 8 and 5 weeks after seeding, so that in the last instance the latest urea treatment was only 2 weeks before sampling.

Even without urea all samples were in excess of 4 per cent total nitrogen, showing the value of the clover pasture. In each instance urea had increased the nitrogen content at both rates, and more by later application. The youngest plants were also highest in nitrogen status.

2. Wheat.—(a) Wheat tops, winter cut, from Wongan Hills had received 50, 100, 150 or 200 lb per acre superphosphate or the equivalent of calcined rock phosphate. Even the maximum rate of rock phosphate did not produce phosphorus levels equal to the minimum of super. The 50 lb per acre of superphosphate increased phosphorus concentration compared with no fertiliser by 70 per cent and 132 lb per acre of calcined rock phosphate increased phosphorus by 33 per cent.

In a similar experiment at Chapman, but with rates of 40, 80 and 120 and 160 lb per acre of superphosphate, the phosphorus in untreated wheat tops was 50 per cent higher than at Wongan Hills and the use of superphosphate, let alone rock phosphate, made little increase even at the maximum rate.

Spring cuts at Wongan Hills showed phosphorus as slightly less in treated than in untreated wheat tops, the levels being about half that of the untreated plants in winter, and the Chapman spring cuts confirmed this finding.

(b) On land at Badgingarra, which had a prehistory over 4 years of receiving between 50 and 600 lb per acre of superphosphate while carrying lupins, a comparison was made between broadcasting 224 or drilling 150 lb per acre superphosphate and a combined treatment consisting of a dressing of 112 lb each of potash (KC1) and magnesium sulphate together with 100 lb of urea in 4 dressings of 25 lb per acre.

The superphosphate added in the current year increased the average phosphorus concentration from 0.34 per cent to 0.40 per cent but did not improve nitrogen status, by either method of application. The combination treatment while showing a slight suppression of phosphorus, improved the nitrogen content from 1.70 to 1.86 per cent.

(c) As part of an extensive study at Wongan Hills Research Station of the use of anhydrous ammonia compared with urea, nitrogen levels in the wheat tops were again determined.

The ammonia was applied either 4 weeks before or at seeding at depths of 4, 6 or 8 in. and at rates of 28, 54 and 67 lb per acre. The urea was used at rates equivalent in nitrogen, and 4 weeks before, at, or 3 weeks after seeding.

Ammonia applied at 4 and 6 in. tended to give increased nitrogen concentration if applied before seeding, but plants receiving ammonia at 8 in. and at seeding were slightly higher in nitrogen than if treated earlier. Urea applied after seeding distinctly improved nitrogen concentration compared with the other times of application. Ammonia and urea differed little if applied at the most advantageous time, but the best performance in respect of nitrogen concentration was from ammonia applied at 6 in. depth 4 weeks before seeding.

A replica of this experiment on the same Station, on a different soil type with more organic content showed the same benefit from early application of ammonia, the benefit extending to the 8 in. depth of application. Urea application either before or after seeding gave improved results compared with at seeding and again the 6 in. depth 4 weeks before seeding was best for ammonia.

(d) Samples of wheat grain from an old land trial at Esperance, estimating superphosphate and urea needs for a second crop, showed that although there had been a large yield response to urea and a small one to superphosphate neither the nitrogen nor phosphorus levels followed this pattern.

(e) Wheat tops, roots and leaves from an experiment conducted in the phytotron in Canberra, to examine the photosynthesis of wheat (Gamenya) under different environmental conditions, were analysed for total nitrogen. Plants were grown either at 18° C day temperature and 13° C night or 12° C day and 7° C night. Half of them were fed nitrogen at 14 milliequivalents per litre continuously from planting and the other half received nitrogen for for only 5 weeks.

For the tops, those which received continuous nitrogen contained a greater concentration under the warm conditions, but where nitrogen was stopped the greater concentration was in the plants experiencing colder conditions. These differences in nitrogen content were found to be repeated in the root samples at lower concentrations, and also in the leaf used for photosynthesis measurement at concentrations higher than found in the whole plant top.

(f) Wheaten straw, grown at Moora on a gravelly soil acutely manganese deficient which had been under pasture for many years, showed no increased uptake of manganese from either 21 lb per acre of manganese sulphate applied to the soil or to the plants as a 4 per cent spray. Levels remained at 5-7 parts per million. The only treatment to improve this concentration was the use of ammonium sulphate at 112 lb per acre together with the manganese sulphate, the content rising to 10 ppm.

Wheat tops from a glass house experiment testing the effect of molybdenum applied to a Bodallin soil which had given a yield response to molybdenum in the field, gave quite anomalous molybdenum results and manganese was found to have been rendered more available in the pot than in the field, of the order of 500 ppm being present.

Samples of the two youngest wheat leaves from plants on various sites where trace element trials were planned, contained at 4 sites between 20 and 30 ppm of manganese, at a fifth 14 ppm and where plants showed deficiency symptoms only 8 ppm.

(g) Wheat tops and roots grown at Lancelin on yellow sand which was acutely deficient in copper and supposedly in zinc, had received various combinations of copper sulphate up to 15 lb per acre with and without zinc oxide up to 4.5 lb per acre. Copper treatment did not significantly improve copper status until 7.5 lb per acre or more were used. The untreated plants contained 36 ppm of zinc which did not support the suggested zinc deficiency and this was not greatly varied by zinc oxide treatments. There was no evidence of copper zinc interaction.

(h) Wheat tops from Bodallin had received superphosphate and roasted molybdenite with varying combinations of copper sulphate and/or zinc oxide to test uptake of copper and zinc and any possible interaction effects.

Even those samples which had received 7.5 lb per acre copper sulphate remained at less than 2 ppm copper, but there was a tendency for those which had received zinc oxide in addition to contain even lower levels of copper. Zinc was also low in spite of treatment, but from an untreated content of 6 ppm, 0.5 oz. per acre of zinc oxide raised the level to 8.5 ppm and 3 oz. per acre increased it to 10 ppm irrespective of copper fertiliser.

(i) Wheat grain from 3 different sites was tested to check the suggestion that grain molybdenum content may be a satisfactory indicator of the sufficiency or otherwise of the molybdenum supply for maximum grain yield.

At one site, when molybdenum was supplied together with copper and zinc, the resulting yield increase was about 50 per cent, but at least half of this increase was obtained by copper and zinc alone. The molybdenum content had doubled by molybdenum treatment of 2 oz. per acre of molybdenum trioxide. Another site in the same district, while it gave a 100 per cent yield increase with the trace element mixture, in fact had a lower concentration of molybdenum in samples receiving molybdenum fertiliser and the whole of the increased yield was attributable to copper and zinc.

Wheat grain from Merredin Research Station, better fitted the postulate that grain molybdenum content would indicate molybdenum availability. Application of molybdenum trioxide increased yield by 0.5 bushels alone, or by 4 bushel per acre with the further addition of 175 lb per acre of ammonium sulphate. Molybdenum content of the grain was increased by 0.5, 0.75, 1.5 and 3 oz. per acre of molybdenum trioxide, from 0.04 ppm without treatment to 0.06, 0.08, 0.12 and 0.16 ppm Mo respectively.

The high yielding grain contained 0.10 ppm molybdenum which related more to the 1.5 oz. per acre of molybdenum trioxide alone, and was typical in that nitrogen supplied either as urea, sulphate of ammonia or sodium nitrate tended to slightly suppress molybdenum concentration.

Thus molybdenum content of wheat grain may be a satisfactory indicator of sufficiency or deficiency for maximum grain yield, but this will only be where no other factor is limiting.

Plant Nutrition.

1. Apples—(a) Leaves from unthrifty Granny Smith trees at Kirup with an unusual amount of dieback were deficient in both phosphorus, 0.08 per cent, and nitrogen, 1.80 per cent, and at the critical level of potassium, 1.25 per cent, by the assessment of Emmert, (N.Z. J. Agr. Res. 1962, 5, 381.)

Further unthrifty trees in the next season had phosphorus at the same level, nitrogen down to 1.4 per cent but rather better potassium at 1.56. These were also tested for copper, containing 4 ppm, considered deficient by Dunne J. (Dept. Agri. W.A. 1938, 15, 124.)

Other Granny Smith trees had been treated by phosphorus and calcium applied in a number of different ways but as so often with such work variation between duplicate samples masks results and prevents any firm conclusions.

A more hopeful experiment was at Bridgetown where several different fertiliser treatments and cultivation practices were assessed for nutrient uptake. Calcium, nitrogen and phosphorus were all most benefited by supplying a complete fertiliser including trace elements and having a mown permanent sod. Potassium also improved by this practice but not to the extent obtained by using a deep sawdust mulch with nitrogen fertiliser.

Further work on Granny Smith trees at Manjimup involved spraying with a mixture containing copper, manganese, calcium and magnesium. The spray was believed to have caused staining in both 1 and 2 year old wood. Copper was the only one of the additional elements consistently higher in the stained wood, being of the order of 6 to 8 times the concentration in wood of the same age in unsprayed trees.

(b) Many other apple leaf samples were examined for diagnostic purposes; from Karagullen because they were believed to be trace element deficient; from Brookhampton for sulphur and magnesium; from Stoneville where trees deficient in calcium and phosphorus were to receive a variety of phosphate treatments and from Denmark where boron spraying was shown to be unnecessary.

2. Pears.—Comparison of leaves from trees at Parkerville said to be vigorous or poor, showed the overall nutrient status of the better trees to be at high levels for all macro and minor elements. Further leaves from Roleystone contained 8-12 ppm of copper and 19 to 24 ppm zinc, which were probably adequate, but manganese at 15-17 ppm could be a limiting factor.

3. Citrus.—(a) Leaves from four varieties of citrus which were growing at Karalundi Mission, Meekatharra, exhibited symptoms resembling boron toxicity. The boron content was found to range

from 660 to 1,200 parts per million which was consistent with the diagnosis. Bore waters from the Mission had previously been found to contain 1.8 and 2.3 parts per million boron. 0.5 ppm has been reported as the safe limit for irrigation of citrus.

(b) In a trial at Stoneville where both Navel and Valencia oranges had been grafted on to 5 different root stocks the most consistent performance from the point of view of nutrient uptake was given by trifoliata.

The order of performance, considering both macro and minor elements with Navel orange grafts was trifoliata, cleopatra mandarin, sweet orange, citronelle and citrange. For Valencias the only difference was the interchange of sweet orange and citronelle in 3rd and 4th places.

(c) Urea at 0.5, 1 or 2 lb per tree, superphosphate at 2 lb per tree and potash at 1 or 2 lb per tree were used in a variety of combinations on oranges at Capel.

Urea at 0.5 lb was sufficient to provide a satisfactory nitrogen level, and neither phosphorus nor potassium gave an interaction. On the other hand phosphorus level, unaffected by superphosphate treatment, was enhanced slightly by the use of potash and suppressed by increased rates of urea.

The nutrient showing the greatest change by treatment was potassium. The use of 2 lb per tree of potash (KCl) doubled the potassium content. Phosphate did not affect the potassium concentration but as with phosphorus, urea decreased it.

4. Bananas.—For eelworm control, bananas at Carnarvon are treated at frequent intervals with a brominated hydrocarbon (P.B.C.P.) in the irrigation water. Some plantations exhibit abnormal growth symptoms following prolonged treatment and to test whether bromide accumulation was involved, young and old leaves from healthy and poor growth in treated areas and healthy leaves from untreated areas were compared.

The following results were obtained:

Sample			Bromide, Br parts per million dry basis
I	Treated-poor growth	youngest expanded leaf	300
II		old leaf	200
III	Treated-normal	youngest expanded leaf	260
IV		old leaf	280
V	Untreated	youngest expanded leaf	50
VI		old leaf	90

This shows that there is accumulation but does not explain the difference between healthy and poor growth of the plants being treated for nematodes.

To see what the effects on nutrient levels had been, or to see if nutrient levels might explain the symptoms the other elements tabulated (Table 3) were determined after semi-quantitative spectrographic analysis had shown possible differences in levels.

Table 3

Banana Leaves

Sample	I	II	III	IV	V	VI
			dry basis per cent			
Ash	14·1	13·8	13·0	15·9	12·2	15·8
Calcium, Ca	1·00	1·00	0·57	1·21	0·63	1·89
Magnesium, Mg	0·48	0·40	0·42	0·45	0·41	0·53
Potassium, K	5·24	4·42	5·88	3·73	5·27	3·43
Sodium, Na	0·03	0·06	0·03	0·04	0·01	0·06
			parts per million			
Copper, Cu....	10	5·3	9·6	4·8	11	3.6
Iron, Fe	210	260	160	450	170	360
Manganese, Mn	880	1500	340	3200	210	560
Zinc, Zn	22	24	21	20	18	17

There is some build up in calcium in the poor, treated young leaves, but levels generally would be considered deficient in other fruit species. It is possible that the manganese build up in these same leaves is significant but further data would be needed to draw firm conclusions.

5. Beans.—Beans which were growing at South Coogee on soil which had received 30 cubic yd. of sewage sludge more than one year previously, were stunted and had pale leaves. The worst were only 4 to 8 in. high with chlorotic, scorched and distorted leaves. Analysis showed very little difference in copper, zinc or manganese in the healthy or moderately affected leaves, but concentrations in the worst leaves were more than doubled.

To study further the toxic effects of using sewage sludge as fertiliser, runner beans were sown at Medina Research Station on tuart sand typical of the region and treated with 20, 40 and 80 tons per acre of sludge from the Subiaco Sewage Treatment Works. Leaves showed increasing concentation of copper, zinc and manganese with increasing severity of symptoms at the time of flowering. When these same beans were ready for picking one month later they were again sampled and analysed with similar results.

The ash of untreated whole plants and those receiving maximum treatment were spectrographically examined and it was found that the total mineral content of the affected plants was double that of the healthy untreated ones, 18.7 per cent and 9.7 per cent respectively.

It seems advisable that for such sensitive plants as runner beans alternative fertilisers are preferable, and that some work on less sensitive plants to establish safe and economic levels of sludge as fertiliser is justified.

6. Cauliflower.—Toxicity symptoms, believed to be induced by soil fumigation causing release of available nutrients, failed to relate to nutrient concentrations.

Other cauliflowers on a particular patch of a York property showed a corky condition of the midrib on both the upper and lower surfaces, browning of the curd, lesions of the pith, leaf distortion and slight mottling. The indicated boron deficiency was not confirmed when both healthy and affected plants were found to contain 31 ppm of boron.

7. Celery.—Plants growing in sprinkler shadow on a property at Balcatta had symptoms resembling those of "whiptail" in cauliflowers, a molybdenum deficiency which appears in these conditions. Healthy plants from the property contained 1.2 ppm molybdenum and distorted plants 0.53 ppm.

Animal Nutrition.

1. Cobalt and Copper.—(a) 80 sheep livers removed after pathological examination of sheep used in lupinosis studies at Badgingarra were tested for copper, copper storage being one of the factors relating to this "disease".

(b) Other samples were associated with mortality at Esperance where livers contained cobalt 0.33 ppm and copper 120 ppm; suspect deficiency at Gibson, cobalt 0.10 ppm and at Wokalup 0.30 ppm.

2. Manganese.—Infertile heifers from Bramley Research Station were culled. The manganese content of their livers was determined, and ranged from 1.6 to 4.6 ppm for non-pregnant beasts but in two found with foetuses the values were 5.6 and 6.9 ppm. Other livers from infertile beasts were subsequently found to contain from 1.9 to 8.8 ppm of manganese.

3. Selenium.—(a) Sheep which were drenched with a 50 mgm dose of selenium instead of a 5 mgm dose died. Kidney from three of the affected sheep contained 25-32 ppm dry basis of selenium.

(b) Ill thrift in a Harvey dairy herd was associated with a selenium liver content of 0.2-0.3 ppm of selenium.

4. Miscellaneous.—Further samples included phosphorus and fluoride contents of bones, hair for manganese which may affect colour and a survey of tocopherol (vitamin E) in sheep livers.

Miscellaneous.

1. Blood Alcohol.—65 samples of blood were analysed for alcohol either as a check against results by another method used elsewhere in the Laboratories or tests of the Breathalyzer.

2. Chemicals.—Sulphuric acid used in a pickling bath was tested for acid and iron content, and a firm of instrument makers was advised that measurement of either specific gravity or specific conductivity was adaptable for an automatic indicator to determine the need for replacement of the acid.

Copper sulphate, used by the Metropolitan Water Supply to control algae, was found to meet specifications for such material.

3. Test Kit.—A kit of American manufacture for measuring available chlorine and pH of swimming pool water, while it failed to meet the requirements of the Health Act Regulations for use with public pools, was suitable for domestic pools.

4. Photographic.—Faults in photographic prints of maps prepared by the Drawing Office of the Public Works Department, were caused by discontinuity of the silver image of the prints, and were not found in the negatives. The faults were corrected by the use of a diffuser in the recorder.

Water Treatment and Supply.

1. Corrosion, Scales and Deposits.—(a) Exmouth Water Supply is very hard, varying from about 300 to 400 parts per million (20-30 degrees) of total hardness. Trouble from its use is therefore to be anticipated and the first such was a deposit which formed in the heat exchange coil from the oil fired hot water service at a caravan park. The deposit was calcium carbonate, the unsoftened water being unsuitable for use in a hot water service.

If softened completely the water would become corrosive because of its relatively high dissolved solids content and a short life only could be predicted for copper heat exchanger tubes. In practice however a base exchange softener does not completely soften the water and some scale may still form to protect the pipes. To make sure, approximately 20 per cent of the untreated water could bypass the softener. Acid descaling would then be necessary but not nearly so frequently as with unsoftened water.

(b) Another Exmouth problem was corrosion of deep well pumps which was either contributed to by, or resulted in, some lubricating oil getting down the wells. Corrosion products from the steel portions of the pumps were blocking surface filters. As explained above, the water being scale forming, corrosion was not anticipated with this water.

It seemed probable that there were a number of contributing causes and stages in the corrosion since the brass strainers from the bottom of the bore raised for inspection had completely corroded away, although no copper was found in the present corrosion products. The gelatinous internal portion of the corrosion product containing the less oxidised form of iron oxide suggested there had been bacterial action.

It was recommended that when further pumps were withdrawn for maintenance samples correctly taken for bacteriological examination be forwarded to the Microbiology Department of the School of Medicine whose co-operation had been offered. If bacterial corrosion was confirmed shock dosing with chlorine would be the most satisfactory method of control.

(c) A deposit found in the chilled water lines at Port Hedland Hospital contained small flakes of nickel but consisted mostly of copper oxide, a corrosion product which could not be very readily removed by other than mechanical means. It was most unusual to find this type of corrosion in a chilled water system and suitable treatments were advised.

(d) At Sir Charles Gairdner Hospital corrosion of the copper pipes of the hot water system was thought to be primarily due to dissolved oxygen released in the system and possibly high temperatures. It was advised as a first step to fit air eliminators, secondly to control the temperature of water entering the distribution system to about 160°F, and thirdly not to use untreated condensate water in the make up.

Failure of these measures would mean that chemical treatment of the make up water would be needed.

Subsequent inspection revealed no benefit being obtained from the eliminators as installed and their relocation, together with pH control, was advised.

(e) The copper roof of the plant room of the Government Buildings, King's Park Road, was reported to be corroding due to the gases from the nearby flues from oil burning furnaces. Corrosion was confirmed as due to sulphur products from the burnt oil not being properly carried away because of the design of the chimney. Recommendations for modifications were made.

(f) The deposit forming in the cooling system of Western Australia House in Darwin was a calcium carbonate scale. Waters from the mains supply and the condenser sump showed that there had been a 25 fold concentration leading to the precipitation of the hardness salts.

The scale could be removed readily with inhibited acid and to prevent recurrence either the total salts should not be allowed to concentrate more than 2 to 3 fold by setting the bleed off, or the make up water should be softened. Even with softening the total dissolved solids should not exceed 1,000 ppm, a tenfold factor. The use of polyphosphate at approximately 10 ppm would provide additional control of either scale or corrosion.

Too much faith must have been placed in the reputation of Darwin's water. The mains supply in October 1966 had total dissolved solids of 90 ppm compared with Serpentine water of 200 ppm at the same date, but Darwin water contained 70 ppm of hardness compared with only 40 ppm in the local supply.

2. Metropolitan Water Supply.—(a) Further testing of Hills Catchment Water confirmed that the chlorination dosages were satisfactorily giving just in excess of breakpoint chlorination. Tests carried out along the mains from the hills to the holding reservoirs in the suburbs showed that growths in the pipes were no longer taking up chlorine, that growth had probably been controlled as was intended and that sterile conditions confirmed by bacteriological testing, were being obtained.

If a free residual chlorine of 0.2 parts per million is maintained at the discharge end of the pipelines this should ensure effective chlorination throughout this portion of the system.

(b) Routine testing of sources i.e. Hills Catchments and artesian bores, holding reservoirs and reticulation points, and experimental catchments, was intensified. This was in order to provide a better picture of fluctuations in quality in the distribution and the way in which mixing in individual reservoirs of the source waters might affect consumer complaints resulting from taste changes in particular.

The effectiveness of dosing with copper sulphate to control algae, which was being closely studied by an officer of the Department of Agriculture, was not complete where the alkalinity, pH and temperature of the incoming water favoured algae growth. However, the combined result of chlorination, more extensive scouring and greater control of bore water admixture has led to a summer of fewer complaints.

(c) A problem which may well become more widespread is the possible distribution into the groundwater of detergents from the soak wells of large blocks of unsewered flats, in particular those on low lying areas. This detergent will then reappear in the water pumped for garden irrigation. The use of biodegradable detergents, of which ordinary soap is the original example, and the system whereby all water passes through the septic tank would be a simple solution.

3. Country Water Supplies.—Once more the extensive programs of the Geological Survey and of the Country Water Supply Branch of the Public Works Department each resulted in almost as many samples as the Metropolitan Water Supply. Geological Survey samples were primarily seeking

supplies for country towns but many are for research purposes as part of the Australia wide interest in water resources.

Treatment of country town supplies, in some instances bore waters, some dams from local catchments and others supplied in part from Mundaring or Wellington dams, produced many problems.

Wyalkatchem, Jerramungup, Narrogin, Borden, Ongerup and others all had their problems of either clarification or chlorination, and rates of chemical addition were advised. In some instances the towns were visited while treatment was carried out or subsequently to test the effectiveness of the operation.

Albany and Esperance each had problems with the functioning of their water softening processes and at Denmark, where the water is decolorised, overdosing with alum had led to carry over of aluminium in solution which was precipitating following pH correction.

Eaton, Yunderup and Boyanup each had problems due to the iron content of the bore waters making up their supplies. Iron can be removed by aeration, perhaps with chemical dosing, in addition, followed by settling and filtration, but the establishment of the optimum conditions is rarely the same for any two waters.

Conferences and Talks.

Mr. J. Jago attended the Australian Soil Science Conference in Brisbane in May.

In July, Mr. J. Jago gave a talk entitled "Report on Soil and Plant-tissue Testing in Australia" to the W.A. Branch of the Australian Society of Soil Science.

ENGINEERING CHEMISTRY DIVISION

With the return in January of the Chemist and Research Officer, Grade 1, Mr. R. G. Becher, from leave in Europe, the strength of the professional staff of the Division was restored to normal, viz. four, including Divisional Chief.

From fifteen projects tackled by the Division during the year, twelve, or 80 per cent of the total were carried out in response to requests from outside interests, one among them being sponsored by a N.S.W. firm on an ore from Tasmania.

Three of the Division's own research and development projects into the utilization for industrial purposes of natural resources of this State viz. (a) the utilisation of titaniferous vanadium bearing magnetite at Coates, (b) the production of lightweight aggregate for concrete, from local shales on the pilot plant scale, and (c) the effect of methods of heating limesand on its beneficiation by electrostatic separation of silica, were carried over from the previous year and continued during the year as time permitted. These projects were assigned a lower priority as compared with sponsored projects.

The planning of the extensions of the office and of the laboratory building was finalised by the end of 1966, and the work was scheduled to start early in 1967.

Also the planning of a centralised oil firing system for all oil-fired furnaces of the Division, by the erection of an oil ring-main. and the installation of an underground oil tank and for the conversion of the steam boiler to oil firing, was finalised this year, the installation being expected to commence early in 1967.

Utilisation of Titaniferous Vanadium Bearing Magnetite Deposits, Coates Siding.

This work was initiated in 1964 to find ways and means for the industrial utilisation of deposits at Coates, possibly at Wundowie Charcoal Iron and Steel works.

The description of the deposits, containing an estimated 8.2 million tons of weathered ore and possibly over 32 mililon tons of original gabbroic rock (ore), together with the results of bench scale investigations, carried out in these years, were given in the Annual Reports for 1964 and 1965.

During the period under review, a theoretical appraisal was made of some processes which could possibly be applied to this ore.

Four processes, viz. Krupp-Renn, Halomet, Otanmaki and Reduction Acid Leaching processes, were critically examined.

Krupp-Renn Process: Relevant literature was translated where necessary, and studied. One interesting aspect arising from this study, was the possibility of using "red mud" from alumina refining, and pyrites calcines, as components of the feed mixture for a Krupp-Renn kiln. This may not be of interest at Coates, but could be considered for possible large scale operations in the Kwinana area.

An authority in Germany, who had much to do with the original development of the Krupp-Renn process, was contacted and consulted on the problem.

It was confirmed that the Coates ore could be treated by the Krupp-Renn process, but doubts were expressed concerning technical feasibility of the extraction of vanadium or titanium from the slag.

Thus, the process could be operated for iron recovery only, unless a modified ore concentration procedure, as suggested by this authority, was applied. It is proposed to investigate the possibility of applying this modification to concentrating the ore.

Calculations were made of probable slag compositions resulting from Krupp-Renn treatment of Coates ore, suitability of slags for operation of this process being determined by entering the calculated composition onto the ternary diagram.

The results of these calculations are summarised in Table 4 Halomet Process: From the somewhat incomplete information contained in the printed pamphlet, issued by the Tellus (A/G) fur Bergbau und Huttenindustrie in Frankfurt-am-Main, Germany, and the correspondence with the above Company, a probable flowsheet of the process was drawn up, as shown in Figure 2.

The probable total consumption and cost of chlorine were calculated for the process as applied to Coates ore as shown in Table 5.

At the January 1966 Australian price for bulk chlorine ($170 per ton, in drums), there seems little likelihood of such a process being economic for unaltered gabbro or for a mixture of the whole ore as mined. However, chlorination could possibly be considered for the treatment of weathered ore alone, since most of the unwanted chlorine-consuming components of the ore have been leached out in the process of weathering of the gabbro.

Otanmaki Process: An ore containing vanadiferous magnetite, together with ilmenite and iron pyrites, is mined and processed at Otanmaki, Finland.

An outline of the process, presented in Figure 3 has been drawn from information in the literature and from the comments made by Mr. R. G. Becher, who during the leave in Europe visited also Otanmaki works.

If a similar process were applied to Coates ore, treating only the unaltered gabbro—since it is probably not applicable to weathered ore— the expected grades of product and overall recoveries would be as shown in Table 6.

Vanadium extraction efficiency was assumed to be similar to that obtained at Otanmaki, although somewhat better vanadium extractions have been obtained in laboratory tests in this Division using finely ground material rather than relatively large pellets as at Otanmaki.

Reduction/Acid Leaching Process.—This process has been outlined previously and is shown diagrammatically in the Annual Report for 1965.

Good separation and recoveries of iron and vanadium were obtained from the magnetic concentrate of unaltered gabbro. However, the application of this process to weathered ore gave very poor recoveries of vanadium, and it would appear unlikely that the process could be applied to the whole ore as mined.

Table 7 shows the likely overall recoveries from the total ore.

FIGURE 2.

HALOMET PROCESS

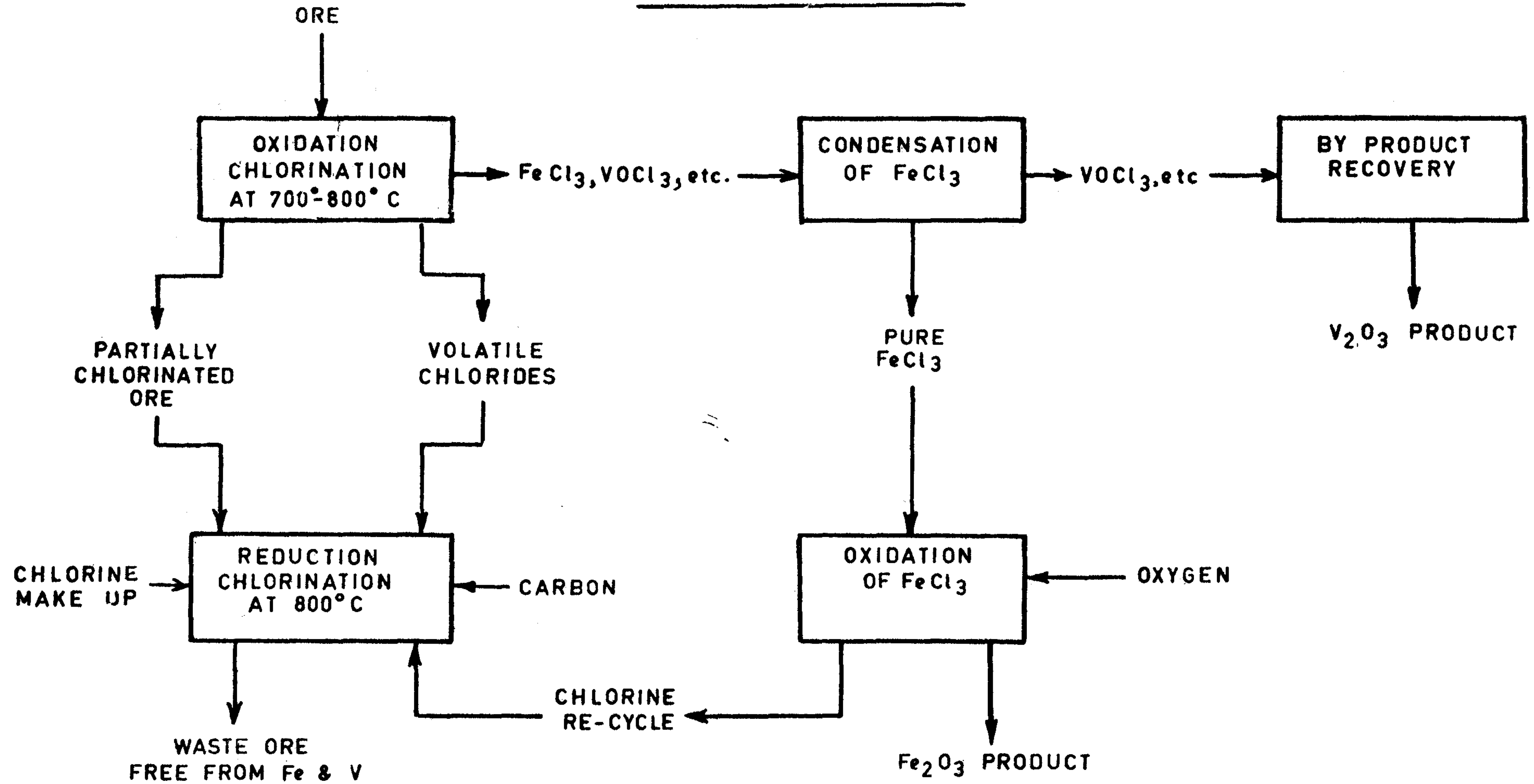


FIGURE 3.

OTANMÄKI PROCESS.

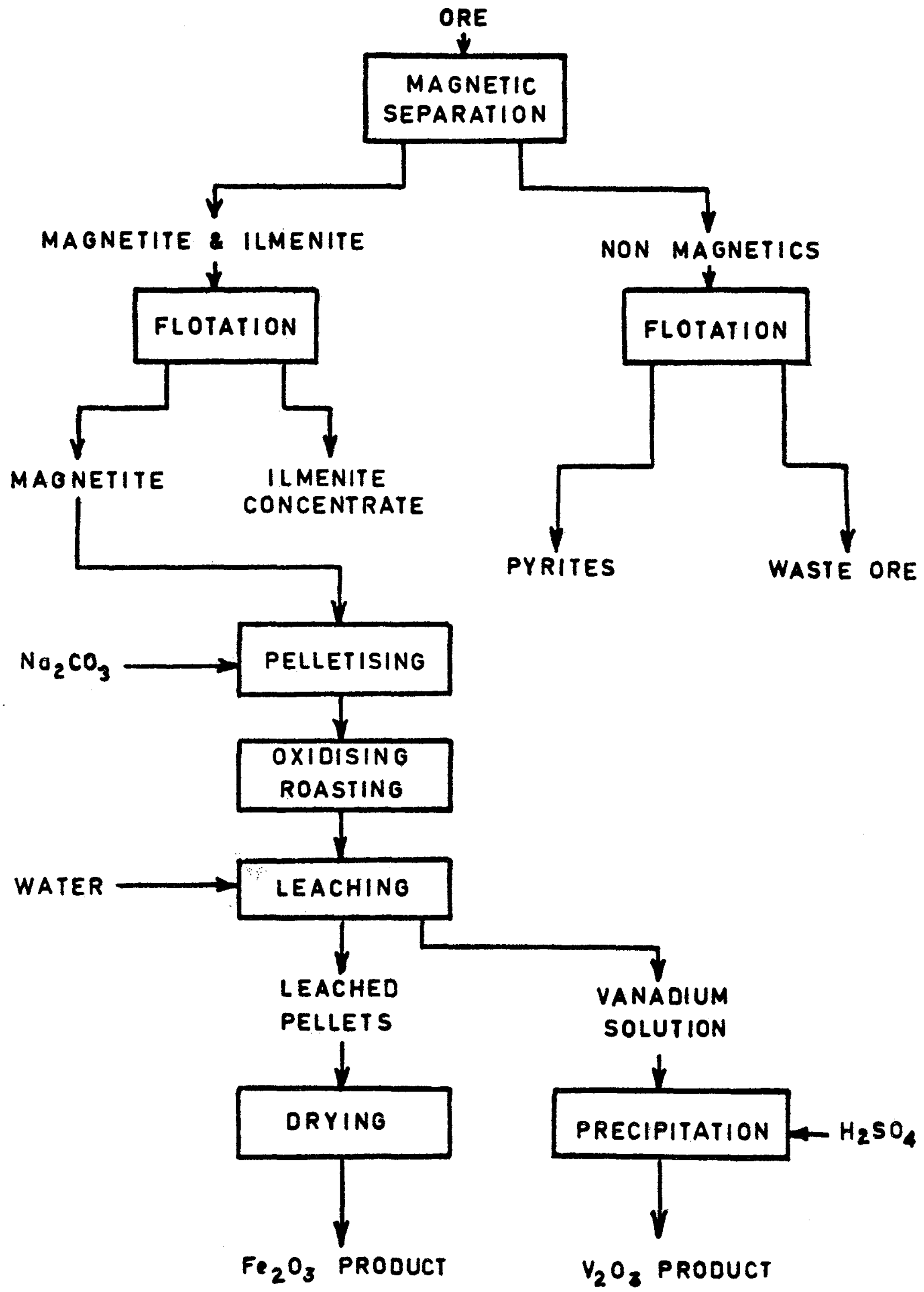


Table 4

Krupp-Renn Slag Compositions

	A	B	C	D	E
Feed Mixture—					
Ore feed	Unaltered gabbro	Weathered ore	Weathered ore	3 part gabbro + 1 part weathered ore	2 parts gabbro non-magnetics + 1 part weathered ore
Additive	Nil	Nil	28 per cent. limestone*	Nil	Nil
Total iron in ore, per cent.	27·8	26·6	26·6	27·5	18·3
Feed Components per 100 parts of ore feed—					
SiO_2 (+ TiO_2 equivalent), per cent.	33·9	27·5	30·3	32·4	38·4
Al_2O_3, per cent.	12·7	19·2	19·2	14·3	18·2
CaO (+ other alkali equivalents), per cent.	11·4	0·5	14·6	8·7	10·0
Ratio $\frac{SiO_2}{Al_2O_3}$	2·7	1·4	1·6	2·3	2·1
Ideal CaO† content of slag, per cent. (corresponding to $\frac{SiO_2}{Al_2O_3}$ ratio)	16	28	26	18	20
Calculated Slag Composition—					
SiO_2, per cent.	55·5	55·4	44·9	55·6	54·7
Al_2O_3, per cent.	20·8	38·6	28·5	24·5	26·1
CaO†, per cent.	23·7	6·0	26·6	19·9	19·2
Suitability of slag for Krupp-Renn operation	Too fluid	Melting point too high	Satisfactory	Satisfactory	Satisfactory
Calculated Product Quantities per 100 parts of ore feed—					
Weight of Fe metal	24·9	24·2	23·4	24·7	14·9
Probable Fe recovery, per cent.	90	91	88	90	82
Weight of slag	62·9	52·4	70·4	60·3	71·8
$\frac{slag}{metal}$ weight ratio	2·5	2·2	3·0	2·4	4·8
Maximum V—content of slag, per cent.	0·46	0·55	0·41	0·48	0·21

* Limestone assumed to be 90 per cent. $CaCO_3$, 10 per cent. SiO_2.

† CaO is the sum of all basic components expressed as CaO equivalents, and includes an average FeO content (6 per cent.) of slags.

Table 5

Calculated Cost of Chlorine for Chlorination of Coates Ore.

	Unaltered gabbro	Weathered ore	Total ore as mined, (i.e. 3 parts gabbro + 1 part weathered ore)
Calculated chlorine consumption, tons/100 tons ore	12·05	2·46	9·65
Cost of chlorine*—			
per ton of ore, $	20·50	4·20	16·4
per ton of contained Fe, $	73·80	15·70	59·50

* Chlorine at $170 per ton.

Table 6

Application of Otanmaki Process to Coates Ore.

	Analysis of product			Recovery of components from total ore			
	Fe	V_2O_5	TiO_2	Total Wt.	Fe	V	Ti
	per cent.			per cent.			
Total ore	27·5	0·52	6·0	100	100	100	100
Pure V_2O_5	....	99*	....	0·20	....	36*	....
Fe_2O_3 pellets	56	0·38	11·0	24	49	17	43
Combined tailings and waste ore	18	0·27	4·5	77	51	40	57

* Vanadium oxide grade and recovery from magnetite were assumed to be similar to those obtained at Otanmaki.

Table 7

Reduction/Acid Leaching Process.

Treating only magnetic fraction of unaltered gabbro.

	Analysis of Product			Recovery of components from total ore mined			
	Fe	V_2O_5	TiO_2	Wt.	Fe	V	Ti
	per cent.			per cent.			
Ore mined (3 gabbro + 1 weathered ore)	27·5	0·52	6·0	100	100	100	100
Iron metal powder	99·0	0·1	0·3	12·5	45·0	2·0	0·1
Pure V_2O_5	....	99	....	0·24	....	45·0	....
Titaniferous residue after V_2O_5 extraction	4·0	1·3	60·0	3·0	0·5	7·5	30·0
Combined tailings (weathered ore + non-magnetics from gabbro)	18·0	0·27	4·5	77·0	51·0	40·0	57·0

Table 8

Comparison of Processes

	Krupp-Renn	Halomet	Otanmaki	R/AL
Ore treated	Total mined	Total mined	Gabbro	Gabbro
Raw Materials Required* Major	Char Fuel oil or coal	Chlorine Oxygen	Sodium carbonate	Coal and char Hydrochloric acid Hydrogen
Minor	Limestone	Char	Sulphuric acid	Sodium chloride Sulphuric acid
Major Processing Steps	1. Grinding and mixing 2. Kiln treatment 3. Crushing and magnetic separation of "luppen"	1. Grinding 2. Chlorination 3. Condensation and separation of volatile chlorides 4. Fe_2O_3 and Cl_2 recovery 5. V_2O_5 recovery	1. Grinding 2. Magnetic separation 3. Re-grinding and flotation of ilmenite 4. Mixing with Na_2CO_3 and pelletising 5. Roasting 6. Leaching of V 7. Precipitation of V_2O_5	1. Grinding 2. Magnetic separation 3. Reduction roasting 4. HCl leaching 5. $FeCl_2$ crystals by evaporation 6. $FeCl_2$ reduction and HCl recovery 7. Mixing and roasting with NaCl 8. Leaching of V 9. Precipitation of V_2O_5
Products and Grades....	1. Metallic Fe (luppen) over 90% Fe	1. Fe_2O_3 } High grade 2. V_2O_5 }	1. Fe_2O_3 containing 60% Fe 2. V_2O_5, 99% purity	1. Metallic Fe powder 99% purity 2. V_2O_5, 99% purity 3. TiO_2 residue containing 60% TiO_2
Recoveries of Components in Products	Fe 90%	Fe } probably high V }	Fe 49% V 36%	Fe 45% V 45% Ti (possible product) 30%

* Air, water, heating fuel, and power are also required for all processes.

Comparison of Processes.—A general comparison of the above processes is shown in Table 8, listing raw material requirements, major processing steps, and probable grades and recoveries of the products. Component recoveries are shown as proportions of the total present in the whole ore mined, assuming 3 parts gabbro to 1 part weathered ore to be an average proportion when mined.

The economic feasibility of the Krupp-Renn process is very doubtful in Australian conditions. The Halomet process is unlikely to be economic for Coates ore at the present local price of chlorine, unless only weathered ore was treated by this process.

The Otanmaki type of process might be economical in view of its successful operation in Finland, where mining appears to be more expensive than it would be at Coates, where open-cut method would probably be employed.

The Reduction/Acid Leaching Process should be similar economically to the Hydrochloric Acid Leaching Process for low grade iron ore, as developed by the Research Council of Alberta in Canada.

Light-Weight Aggregate for Concrete.

The work on production from local raw materials of light-weight aggregate to be used in concrete, which was started on a pilot plant scale in 1964 (see Annual Reports for 1964 and 1965) was intermittently continued in 1966. The aim of the work was to carry out more extensive rotary kiln trials based on the results of previous work in the Division.

The investigations were meant to assist in further perfecting bloating techniques of Western Australian clays and shales, and, in particular, to furnish data for the evaluation of aspects of commercial application of the process.

The main raw material used in the work was a bulk quantity of clay reported to have been taken from the Mundijong area in the vicinity of the railway cutting. A small quantity of shale chips from Hawker Siddeley's Cardup quarry was also processed in the kiln. These chips were the left-over from the crushed shale used in the pilot plant work in 1963 (see Annual Report for 1963).

The rotary kiln used for this work was described and illustrated diagrammatically in the Annual Report, 1965, an additional thermocouple being fitted into the kiln exhaust.

The Mundijong clay was reduced to approximately minus 16 mesh size and pelletised, the size of pellets being minus ¾ plus ¼ inch. Pellets were air dried before treatment in the rotary kiln.

Agglomeration of pellets (and chips) in the kiln was controlled by injecting finely ground silica into the kiln by means of an apparatus, designed and built by the Division.

A small quantity of freshly prepared pellets was surface coated by rolling them in powdered silica before drying. The silica-coated pellets were treated as a separate test batch, without injection of powdered silica into the kiln.

The maximum temperature in the kiln was 1,250° to 1,270° C. as indicated by optical pyrometer. Shale chips from the Hawker Siddeley's Cardup quarry showed a tendency to agglomerate when treated at a temperature of 1,260° C. but bloated well without agglomeration below this temperature.

The product from pellets had a bulk weight mostly between 41 and 45 lb per cubic foot, its quality, as determined by visual inspection, being generally high.

The bulk weight of aggregate produced from shale chips indicated:

Size	Per Cubic Foot
Plus 1 inch	31.5 lb
Minus 1 inch plus ¾ inch	35.0 lb
Minus ¾ inch plus ½ inch	37.0 lb
Minus ½ inch	52.0 lb

A feed rate of 200 lb per hour, equivalent to 8.5 lb per hour per cubic foot of kiln volume was attained, this feed rate being considerably in excess of that reported in the literature for pilot and commercial kilns.

A full report on this investigation will be available on completion of the work.

The Effect of the Method of Preheating Limesand on its Electrostatic Beneficiation.

The upsurge of interest in local industrial circles towards the manufacture of high grade lime from calcareous beach sands was an incentive to re-open investigations into one aspect of a process developed by this Division.

In order to produce a high grade lime from limesands occurring within reasonable distance of Perth, it is necessary to first upgrade their calcium carbonate content by removal of silica.

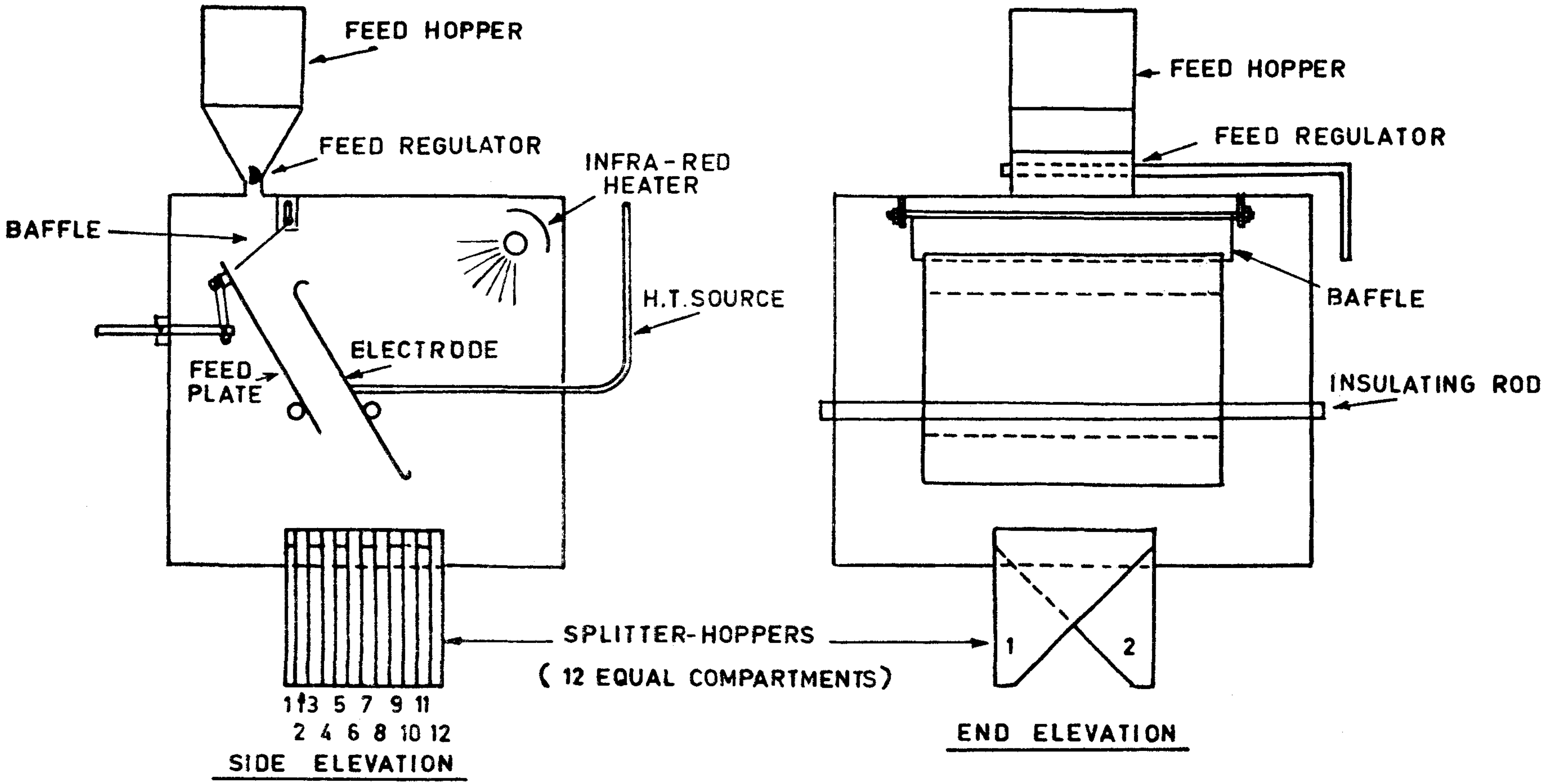
Two such beneficiation techniques had previously been proved effective:

(a) Flotation on a modified Wilfley table (table flotation) and

(b) Electrostatic separation after preheating the sand.

The Engineering Chemistry Division's research work has been directed towards perfecting the electrostatic method.

When assisting a local Company with the commissioning of an electrostatic separation plant for limesand some years ago, difficulties were encountered associated mainly with the methods of preconditioning and preheating the sand prior to electrostatic separation.



INCLINED PLATE TYPE ELECTROSTATIC SEPARATOR

FIGURE 4.

Although a procedure enabling good separation was devised and operated successfully, a satisfactory explanation of the fundamentals of these anomalies was not readily apparent.

The work was re-opened at the end of 1965 and carried over into 1966.

A single stage, inclined plate type separator, specially modified to handle small feed samples and to provide for 12 distinct product cuts, shown in Figure 4, was used for this work.

One series of tests emphasised the advantage of preheating the sand before separation, the preheating to 150°C resulting in a product with 0.3 per cent acid insolubles, and carbonate recovery of 93.0 per cent.

Reversal of polarity resulted in carbonates being attracted towards the electrode plate and the silica repelled. The efficiency, however, was considerably lowered, confirming that a minor constituent can be more effectively attracted to the electrode plate than repelled away from it.

In a series of runs in which pure silica was passed through the separator, the silica failed to respond to the same degree that it had when mixed with carbonates in limesands. All attempts using varying feed rates, increased voltage, and washing the feed before separation, failed to increase the electrostatic response.

The conclusion drawn from this was that efficient separation was the result of a contact potential existing between the individual carbonate and silica grains, and that a precontact was necessary to allow this potential to activate the grains into a "separatable" condition.

A sharp attraction of the silica was recorded when a preheated mixture of quartz and carbonates was treated in the separator.

In order to gain some idea of the time required for efficient charging of particles by contact potential, quartz and carbonates were preheated separately and then allowed only 10 seconds contact time in the hopper before passing the mixture through the separator. A good degree of separation was recorded.

It was established that there were restrictions as to the degree and technique to be used in the preheating of limesands. A good separation can be expected when sand was preheated to temperatures up to 300°C. Above this temperature, separation begins to be impaired, and when heated above 400°C, the sands were rendered almost inert to electrostatic separation.

It is expected to continue this work in 1967.

Upgrading of Ilmenite.

The Division's own project on upgrading of ilmenite beach sands, which culminated in taking out a Letters Patent, was finalised in 1963.

Further development of the process for commercial application was taken over by an industrial firm, which continued investigations on a semi-commercial scale, the Division acting as consultant when requested.

At the beginning of 1966, a request was received from the firm for further pilot plant investigations to be carried out in the rotary kiln and the aeration unit of the Division.

Some investigations in addition to the programme submitted by the sponsor, were suggested by the Division, and accepted by the sponsor. The work, which lasted for several weeks, yielded most encouraging results. The results of the additional work suggested by the Division were of especial value, and were hailed by the sponsor as an important break-through in the prospects of commercial application of the process.

Because of the confidential nature of the work, no details of this and other sponsored projects can be given here.

Calcination of Unbeneficiated Calcareous Sand in Entrained Bed Calciner.

Previous experience gained with the calcination of limesand in the six-inch square entrained bed calciner, built by the Division, emphasised the need for recovering silica from the sand prior to calcination (see Annual Reports for 1961, 1962 and 1963).

However, at the request of a sponsor, an attempt was made to calcine the sand from the Mullaloo dunes in the as received condition, i.e., without the prior removal of silica.

In connection with this request, and as an extension of the Division's own earlier projects, a granular rock curtain was incorporated in the product collection system of the calciner, being located between the settling chamber and the cyclone separator.

This rock curtain was designed to trap fine "sticky" product particles, thereby possibly overcoming the problem of scale formation in the cyclone and the heat recovery system.

Sized diorite chips (average size 1½ in.) were used to form the curtain, and mechanical provisions were made for moving the curtain at regular intervals.

On inspection of the calciner after putting through about one quarter of a ton of limesand, it was found to be generally in good condition.

The cyclone deposits were small in extent, soft and easily removable. The rock curtain section had withstood the temperature satisfactorily, and was mechanically sound. The fines collected on the surface of the rock aggregate were readily removable by screening.

Though these indications were encouraging and in favour of the use of a rock curtain, a longer period of testing is required before passing judgment. This is hoped to be carried out as soon as the pressure of other work will permit.

Investigation into Calcination of Local Limestones.

An evaluation of the influence of kiln variables on the calcination of various local limestones in the rotary kiln of the Division, was requested by a firm and was carried out in 1965. Four limestone varieties from different local deposits were investigated (see Annual Report for 1965).

This year the same firm requested investigation along the same lines, of the limestone from a further four deposits.

Apart from the evaluation of optimum calcining conditions for each type of limestone, the trials were carried out with the intention of producing a sufficiently large quantity of product lime to be physically tested on a larger scale.

Preparation of Char from Collie Coal.

Two requests for the preparation of char with specified qualities from delivered batches of Collie coal were received by the Division during the year.

The carbonisation of coal was carried out in a specially constructed 4¾ in. dia. stainless steel tubular retort of 8 ft. length, the retort being mounted vertically within the heating space of a gas fired furnace.

For reliable temperature control, two thermocouples in vertical sheaths, mounted in the centre of the retort, were able to traverse up and down, and provide temperature readings, longitudinally throughout the centre of the charge.

Apart from the analyses, some additional testing of produced char was requested and carried out.

Magnetic Separation of Tin Ore Concentrates.

A batch of alluvial concentrates consisting mainly of iron and tin oxides was successfully treated on request in the magnetic disc belt separator built by the Division.

The aim was to remove the magnetic iron oxides, which constituted the bulk of the batch, thereby concentrating the tin values, assumed to be mainly cassiterite, in the non-magnetic fraction.

Magnetic Separation of Scheelite Concentrates.

As assistance to prospectors, a batch of scheelite, previously concentrated in a cone, was further concentrated using the magnetic disc belt separator of the Division.

Crushing of Potassium Bifluoride.

As assistance to local industry, a batch of potassium bifluoride was crushed in the pilot plant swing hammer mill.

Hydrometallurgical Treatment of Nickel Sulphide Ore for the Recovery of Sulphur and Nickel.

On the request of a firm, investigations into the possibility of the recovery of sulphur and nickel from a nickel sulphide ore by using hydrometallurgical treatment, was commenced in the second half of the year.

The work was in progress at the end of the year.

Hydrometallurgical Treatment of Tin-Bearing Pyrrhotite.

Investigation into the feasibility of hydrometallurgical treatment of a tin-bearing pyrrhotite was requested by a firm from outside of Western Australia.

This work is still in progress.

Separation of Nickel and Zinc Sulphates.

Assistance in the work on separation of nickel and zinc sulphates, which was to be carried out in the laboratory of a local industry, was requested by this industry in the last quarter of the year.

An officer of the Division was allocated for this work, and was working on the spot as required.

The work was still in progress at the end of the year.

Part Played by the Division in the "Discovery" of Pilbara Iron Ore Deposits.

In 1950-51 the Division, then the Bureau of Research and Development under the Department of Industrial Development, carried out extensive pilot plant work on the production of metallised iron ore, or so called "sponge iron", from Koolyanobbing and Yampi Sound iron ores using Collie coal as reducing medium.

This work was resumed in 1958 as it was conceived that the Commonwealth Government might grant licences for the export of iron ore turned into metallised form, as distinct from the ore as mined, which was under the export embargo.

When in 1960, the then Managing Director of the Griffin Coal Mining Co., Mr. N. Fernie, was about to visit Japan, he was asked by the Division to explore the reaction of the Japanese iron and steel interests towards metallised iron ore, possibly in briquetted form, samples of which were supplied by the Division.

On his return, Mr Fernie reported a considerable interest in Japanese circles, and recognising the value of such an industry in Western Australia he agreed to explore the possibilities of its establishment.

Since the nearest iron ore deposit of sufficient magnitude at Koolyanobbing was not available, it was suggested by the Division that an investigation into the production of metallised ore from low grade ores by their upgrading might be warranted, and such a process might prove economical if the ore were near the coal deposits.

Many such iron ore deposits were located as a result of a search organised by the Griffin Coal Mining Co. Larger samples from three of these deposits, viz., Phoenix Creek, Griffin Creek and Scott River, were tested by the Division for possible upgrading and metallisation, the Scott River ore yielding the most promising results (81.2 per cent metallic iron). The production of metallised ore in a unit developed by the Division, was demonstrated on the pilot plant scale to a special Japanese Sponge Iron Mission, which arrived in Perth in September, 1960.

Further investigations by the Division revealed that, owing to the presence of maghemite, the Scott River ore (the deposits of which were estimated to contain between 60 and 100 million tons), can be upgraded magnetically without metalisation to yield a product acceptable as blast furnace feed (more than 60 per cent total iron).

To confirm this, trial shipments of the ore for metallurgical testing on a larger scale abroad were required, and after some hesitation, the Commonwealth Government permitted its export. This, in fact, broke the export embargo, and apparently influenced the government to reconsider its iron ore export policy, which in turn led to the "discovery" of new iron ore deposits in the North West of the State.

Thus, the technological research work, initiated and carried out by the Division, yielded quite unexpected results culminating in the "discovery" of huge Pilbara iron ore deposits.

Being, to our knowledge, the first among the Australian research and development institutions to tackle the problem of the production of metallised ore from local raw materials on a pilot plant scale, the Division was too much ahead of its time. However, in view of possible use of metallised pellets as blast furnace feed in the near future, the knowledge and experience gained by the Division is likely to be of a considerable value in the future development of our iron ore resources, as it was of a big assistance in the development of the process for upgrading of local ilmenite, now awaiting commercial application.

General.

(1) During the year the Divisional Chief, Dr. S. Uusna, attended six meetings of the Board of Management of the Australian Coal Industries Research Laboratories Ltd., North Ryde, N.S.W. of which he is the member representing Western Australia, and one General Meeting of these Laboratories.

(2) A paper entitled "Some Thoughts on the Use of Pyrites in W.A." was given to the Perth group of the Institute of Fuel, by the Chemist and Research Officer Grade 1, Mr. R. G. Becher.

(3) Research Officers and Chemists Mr. R. G. Becher and Mr. B. A. Goodheart attended a symposium on "Physical Chemistry of Pyrometallurgy" organised by C.S.I.R.O. in Melbourne.

(4) Mr. R. G. Becher and Mr. B. A. Goodheart gave talks to a section of the professional staff of the Government Chemical Laboratories about "Experience gained during one years leave in Europe" and "Utilisation of Western Australian Limesands" respectively.

(5) Advice was given and discussions were held on a wide variety of subjects, including—

(a) lead concentration in tailings of a particular mine;
(b) separation and recovery of pure yttrium oxide;
(c) production of agricultural copper from copper sulphide ores;
(d) utilisation of indigenous sulphur sources for production of elemental sulphur;
(e) treatment of lithium ores;
(f) flash drying of ilmenite sands;
(g) production of "blue" bricks;
(h) best ways for production of char from Collie Coal;
(i) magnetic separation of tin bearing ores, etc.

(6) Among the visitors to the Division during the year were:

Mr. R. A. Cameron, Technical Assistant to the Joint General Manager, Electrolytic Zinc Co., Melbourne.

Prof. F. Yoshida, Department of Chemical Engineering, Kyoto University, Kyoto, Japan.

Mr. W. McDermott, Director, Metallurgy and Research, Pickands Mather & Co., Cleveland, Ohio, U.S.A.

Mr. P. Lynskey, Head of Development, Laporte Titanium, England.

Dr. R. A. Nottle, ICIANZ, Melbourne.

Mr. R. E. Wilmshurst, Officer-in-Charge, Industrial Chemistry Section, Australian Mineral Development Laboratories, Adelaide.

Mr. W. J. Ryan, Research Scientist, AMDEL, Adelaide.

Mr. S. Hudson, Senior Research Scientist, C.S.I.R.O. Ore Dressing Laboratories, Melbourne.

FOODS, DRUGS, TOXICOLOGY AND INDUSTRIAL HYGIENE DIVISION.

As shown in Table 9 most of the samples received by this Division in 1966 were submitted by the Departments of Agriculture, Police and Public Health and by the Milk Board of Western Australia. Lesser numbers were submitted by the Swan River Conservation Board, various hospitals, miscellaneous Government Departments and the general public.

The staff of the Division during most of the year numbered 15 officers, comprising 12 qualified chemists, 2 technicians (in course of qualifying) and one laboratory assistant. Following the completion of building extensions one chemist and one technician were added to the staff, but vacancies for one additional officer of each classification were still not filled at the end of the year.

4,000 samples were received during 1966, being an increase of 11 per cent on the number received in 1965, and a 64 per cent increase over the past 6 years.

A broad outline of the variations in numbers during the period 1961-65 is indicated in Table 10 (selected sample groups):

Table 9.

Foods, Drugs, Toxicology and Industrial Hygiene Division.

	Agriculture Department	Department of Air	Hospitals	Labour Department	Milk Board	Mines Department	Police Department	Public	Public Health Department	Public Works Department	Swan River Conservation Board	Tender Board	Other Commonwealth Departments	Other State Departments	Total
Food—															
Alcoholic Liquor	8	....	....	....	....	....	2	....	20	....	....	....	....	....	30
Apples	15	....	....	....	....	....	....	....	....	....	....	....	....	....	15
Butter	64	....	....	....	....	....	....	....	....	....	....	....	....	....	64
Cheese	25	....	....	....	....	....	....	....	....	....	....	....	....	....	25
Fish	....	....	....	....	....	....	....	....	28	....	....	....	....	....	28
Ice cream	8	....	....	....	....	....	....	....	13	....	....	....	....	....	21
Milk	123	4	....	....	678	....	....	....	60	....	....	....	....	....	865
Various	10	....	4	....	....	....	1	6	14	....	....	....	....	1	36
Industrial Hygiene—															
Blood	....	....	11	....	....	....	....	....	4	....	....	....	....	....	15
Urine	....	....	5	25	....	10	....	101	19	....	....	....	....	....	160
Various	....	....	....	....	....	....	....	....	8	....	....	....	....	....	8
Miscellaneous—															
Animal—															
Baits	26	....	....	....	....	....	....	....	....	....	....	....	....	....	26
Fats	97	....	....	....	....	....	....	....	....	....	....	....	....	....	97
Urine	13	....	....	....	....	....	....	....	....	....	....	....	....	....	13
Blood Alcohol Collection Sets	....	....	....	....	....	....	....	....	12	....	....	....	....	....	12
Bottles	....	....	....	....	....	....	....	....	17	....	....	....	....	....	17
Building Materials	....	....	....	....	....	....	....	8	1	....	....	....	....	2	11
Criminal Cases	....	....	....	....	....	....	62	....	....	....	....	....	....	....	62
Detergents	....	....	....	....	....	....	....	....	....	....	....	70	....	....	70
Explosives	....	....	....	....	....	11	1	2	....	....	....	....	....	....	14
Linseed	16	....	....	....	....	....	....	1	....	....	....	....	....	....	17
Oxygen	....	22	....	....	....	....	....	....	....	....	....	....	....	....	22
Pesticides	94	....	....	....	....	....	....	1	2	35	....	....	....	....	132
Plant Material	162	....	....	....	....	....	....	....	....	....	....	....	....	....	162
Polish	....	....	....	....	....	....	....	....	....	....	....	18	....	....	18
Tallow	....	....	....	....	....	....	....	33	....	....	....	....	....	....	33
Test Plates	298	....	....	....	....	....	....	....	....	....	....	....	....	....	298
Sandalwood Oil	....	....	....	....	....	....	....	22	....	....	....	....	....	....	22
Xylocaine	....	....	....	....	....	....	....	....	13	....	....	....	....	....	13
Various	16	....	12	1	1	5	10	34	28	1	....	6	3	7	124
Pollution—															
Effluents	....	....	....	....	....	....	....	2	2	....	17	....	....	....	21
Maritime	....	....	....	....	....	....	8	....	....	....	....	....	....	....	8
Sewage	....	3	....	....	....	....	....	....	....	....	....	....	....	....	3
Surveys—															
Bunbury	....	....	....	....	....	....	....	....	....	48	....	....	....	....	48
Swan River	....	....	....	....	....	....	....	....	....	....	110	....	....	....	110
Toxicology—															
Animal	19	....	....	....	....	....	3	3	1	....	....	....	....	....	26
Human—															
Specimens from patients	....	....	78	....	....	....	1	11	57	....	....	....	....	....	147
Sobriety	....	....	....	....	....	....	202	3	2	....	....	....	....	....	207
Toxicology	....	1	....	....	....	....	717	....	....	....	....	....	....	....	718
Traffic death	....	....	....	....	....	....	282	....	....	....	....	....	....	....	282
Total	994	30	110	26	679	26	1,289	227	301	84	127	94	3	10	4,000

Table 10.

Class	1961	1962	1963	1964	1965	1966
Foods—						
Total	815	815	656	773	720	1,084
Milks	437	574	382	604	588	865
Exhibits—alcohol	315	331	378	433	458	484
Human toxicology	388	611	649	604	711	718
Industrial hygiene	335	446	233	349	262	183
Miscellaneous	710	608	1,010	883	1,053	1,163
Pesticides	160	231	210	175	153	132
Oil seeds	174	....	342	143	265	16
Toxic plants	....	....	....	....	53	162
Specimens from patients	60	92	97	166	133	147
Pollution surveys—						
Swan River	178	128	128	145	109	110
Bunbury	50	50	48	48	48	48
Total samples received	2,901	3,177	3,279	3,511	3,611	4,000

Foods

1084 samples of food of various kinds were received and examined during the year. 678 of these were samples of cows milk submitted by the Milk Board of Western Australia.

Of this number 296 were samples taken by Inspectors for checking against the chemical standards required by Regulations under the Milk Act. 2.7 per cent of these samples contained less than the legal minimum of milk fat (3.2 per cent) and 71.3 per cent contained less than the legal minimum of solids not fat (8.5 per cent), while 30.2 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 of samples which failed to comply with the standard for solids not fat is somewhat greater than in 1965, but shows a slight improvement in respect of fat and freezing point figures.

The distribution of analytical figures is shown in the following tables:—

Milk Fat.

Per Cent in Sample	Per Cent of Total Samples
Less than 3.00	0.7
3.00-3.19	2.0
3.20-3.49	11.5
3.50-3.74	12.5
3.75-3.99	8.8
4.00-4.99	51.7
More than 4.99	12.8
	100.0

Milk Solids Not Fat.

Per Cent in Sample	Per Cent of Total Samples
Less than 8.00	5.7
8.00-8.24	26.4
8.25-8.49	39.2
8.50-8.74	22.3
8.75-8.99	6.1
More than 8.99	0.3
	100.0

Freezing Point.

Degrees C Below Zero	Per Cent of Total Samples.
Less than 0.510	1.4
0.510-0.519	2.4
0.520-0.529	2.7
0.530-0.539	23.7
0.540-0.550	58.4
More than 0.550	11.4
	100.0

In presenting the above figures it is emphasised that these were Inspector's samples for which there was *prima facie* evidence of their not complying with the legal standards.

An additional 382 samples of bottled milk were taken by Inspectors from metropolitan and country treatment plants for the determination of freezing point only. The distribution of figures is shown in the following Table:—

Freezing Point.

Degrees C Below Zero	Per Cent of Total Samples.
Less than 0.520	Nil
0.520-0.529	1.3
0.530-0.539	33.3
0.540-0.550	65.4
More than 0.550	Nil
	100.0

123 samples of milk received from the Department of Agriculture were analysed variously for lactose (100 samples) protein (31 samples) fat (8 samples) solids not fat (8 samples) and ash (8 samples). These analyses were performed to assist the Dairying Division in the calibration of an infra-red milk analyser (I.R.M.A.).

56 samples of cows milk and 4 samples of canned milk submitted by the Public Health Department were analysed as follows.

32 samples of bottled milk were examined for chlorinated hydrocarbon pesticides by gas liquid chromatography techniques. Dieldrin was detected in all samples but in amounts less than 0.01 parts per million. D.D.T. and its derivatives were detected in one sample in a concentration of 0.01 parts per million, while in five other samples the amounts were less than 0.01 parts per million. No other chlorinated pesticides were detected in any of the samples.

3 samples of milk from cows suspected of suffering from arsenic poisoning were examined for arsenic with negative results.

21 samples of milk were examined specifically for dieldrin. These samples came from cows which had been allowed to graze for three weeks on an area which had previously received a very heavy application of dieldrin. 9 samples were taken three weeks after the cows had been removed from the treated area; the dieldrin concentrations ranged from 0.12 to 0.35 parts per million with an average of 0.22 parts per million. 12 samples taken five weeks subsequently showed that the dieldrin levels had fallen to concentrations which ranged from 0.04 to 0.14 parts per million, with an average of 0.06 parts per million.

4 samples of canned evaporated milk were examined in an effort to determine the cause of incipient deterioration.

4 samples of milk submitted by the R.A.A.F. Base, Pearce, all complied with the general standard for milk prescribed by the Food and Drug Regulations.

7 samples of margarine received from the Department of Agriculture were examined for residues of chlorinated hydrocarbon pesticides. The majority of the samples contained dieldrin and D.D.T. and its derivatives in concentrations less than 0.05 part per million, but one sample contained 0.08 part per million of dieldrin and two samples contained 0.1 part per million of D.D.T. and its derivatives. No other chlorinated pesticides were detected.

25 samples of cheese were examined on behalf of the Dairying Division of the Department of Agriculture. 5 of these samples were analysed as a check on the quality of cheese produced by factories in this State. They all contained more than 50 per cent of fat calculated on a moisture-free basis.

The remaining 20 samples of cheese were examined for chlorinated hydrocarbon pesticide residues, with the following results:—

Pesticide Detected	No. of Samples
Aldrin	13
B.H.C.	14
D.D.T. and derivatives	5
Dieldrin	20
Heptachlor	11

No other chlorinated pesticides were detected.

The amount of individual pesticide present in the samples was always less than 0.05 parts per million and in the majority of samples the amount was less than 0.01 parts per million.

64 samples of butter were analysed for the Dairying Division of the Department of Agriculture. 36 samples were examined to determine conformity with Regulation 58 of the Dairy Industry Act, 1922-1953, and Regulation J.01.002 of the Food and Drug Regulations, 1961, i.e., that butter shall not contain more than 16 per cent of water. Only one sample failed to comply with this requirement.

The remaining 28 samples of butter were analysed for chlorinated hydrocarbon pesticide residues, with the following results:—

Pesticide Detected	No. of Samples
Aldrin	20
B.H.C.	9
D.D.T. and derivatives	7
Dieldrin	26

No other chlorinated pesticides were detected.

The quantity of individual pesticides present in the sample was never greater than 0.06 parts per million and in the majority of samples the amount was less than 0.01 parts per million.

26 samples of imported smoked fish were examined for the presence of artificial colouring and/or evidence of decomposition. One sample was found to contain a mixture of Tartrazine and Acid Orange 10, while another contained what appeared to be two oil soluble dyes which were not positively identified. Two samples of imported canned fish contained Sunset Yellow F.C.F.

Canned sardines, thought to have been responsible for illness, were found to be wholesome and in good condition, and examination of potato chips, alleged to have caused a severe attack of gastro-enteritis, failed to reveal anything responsible for the complaint.

A sample of olive oil, the subject of complaint that it gave an offensive odour when heated, was found to comply with the specifications of the British Pharmacopoeia, except those of Refractive Index and Saponification Value, where the divergence was only marginal. Heating at 350°F for

2 hours on 5 successive days failed to produce any abnormal odour, or any alteration in appearance, colour or flavour.

A sample of home-made melon jam was found to possess an intense bitter flavour, but no toxic substance could be detected by normal methods of examination. Botanical information indicated that the "pie melon" suitable for making jam, is sometimes confused with a wild melon which is often bitter. The pie melon is elongated or oval in shape while the wild melon is spherical and usually characterised by green and white markings on the skin. While not all spherical melons belong to the variety containing the intense bitter principle, the safe rule seems to be to use only those which are elongated or oval in shape.

Four samples of mixed food comprising one day's meals, and the "leftovers" from three days' meals were analysed for calcium in connection with controlled calcium balance studies on a patient suffering from calcinosis universalis

A sample of desiccated coconut suspected of being contaminated was found to contain small crystals of rock salt amounting to approximately five per cent of the sample.

A sample of beer was received from the Liquor Inspection Branch because of suspicion that it was waste beer being used illegally. Analysis showed that its analytical figures were slightly different from those of the "control", but the evidence was not strong enough to support legal action.

9 samples of beer from different breweries were received from the Public Health Department and analysed for cobalt and alcohol content.

A meat pie said to be obnoxious because of a strong flavour of petrol, turpentine or paint thinner was also received but examination failed to reveal evidence of any unusual flavouring. On the other hand two samples of cool drink with objectionable flavour contained evidence of having been contaminated with substances such as fly spray and disinfectant respectively.

Work was continued by the Horticulture Division of the Department of Agriculture on—

(a) the control of "scald" on apples held in "cold storage", and samples of apples which had received experimental treatments with diphenylamine and ethoxyquin were analysed to determine the quantities of each chemical remaining on the skin and absorbed into the flesh of the treated fruit;

(b) the levels of insecticide present in wine made from grapes subjected to treatment with different insecticides used for fruit fly control. Samples of wine were analysed for residues of dimethoate, fenthion and malathion.

Samples of water, tomato sauce and wine were analysed for lead in an investigation by the Publice Health Department to discover the source of lead poisoning in the four adult members of a family. In the light of further evidence, examination for arsenic was also made on some of the wine samples.

Both the Public Health Department and the Dairying Division of the Department of Agriculture were actively concerned about the quality of ice cream being sold on the local market, and 21 samples were submitted for analysis.

Two of these were correctly described as Flavoured Ice, although one sample did not comply strictly with the labelling requirements of the Food and Drug Regulations.

Of the remaining 19 samples—

(a) 8 were ice cream of satisfactory quality, although one was not actually described as Ice Cream on the label;

(b) 3 were ice creams, but were deficient in food solids content. Again one was not described as Ice Cream;

(c) 8 contained varying proportions of vegetable fats; 6 of these were labelled Ice Cream, the other 2 were non-committal.

Human Toxicology.

Samples were received from approximately 330 cases of sudden death which were the subject of police investigation. 154 cases were as a result of traffic accident, while 137 cases, comprising 630 exhibits were submitted for examination for poisons or other physiologically active drugs.

In 43 cases no poison or drug was detected, while in 94 cases a poisonous substance or drug was identified on analysis. Details are listed in Table 11.

Table 11.

Poison or Drug.	No. of Cases.
Carbon monoxide	19
Pentobarbitone	31
Amylobarbitone	22
Quinalbarbitone	9
Phenobarbitone	4
Butabarbitone	2
Cyclobarbitone	2
Barbiturate (not further identified)	3
Carbromal	12
Bromvaletone	2
Amitriptyline	3
Alcohol	2
Chloral	2
Chlorpromazine	2
Phenacetin	2
Thioridazine	2
*Various (one of each)	16
Negative	43

*Ammonia, arsenic, carbamazepine, chlordiazepoxide, chloroquin, cyanide, cyclizine, desipramine, fenthion, hydrochloric acid, kerosene, salicylic acid, solvents ("thinners"), strychnine, sulphamezathine.

As in previous years it was observed that carbromal was usually associated with pentobarbitone, resulting from the ingestion of "Carbrital".

In 55 of the 118 cases where a sample of blood was available, alcohol was found to be present. The concentration of alcohol in the blood was 0.15 per cent or greater in 22 of these cases, and from 0.05 to 0.14 per cent in 30 cases.

Blood Alcohol (Traffic).

282 samples of blood and/or urine were received in connection with investigation into fatal traffic accidents. 154 of these were "post mortem" blood samples which were analysed for alcohol content as a routine procedure.

The distribution of the analytical figures for the various categories of persons involved in these accidents is shown in Table 12.

Table 12.

Alcohol, Per Cent.	Drivers,	Passengers,	Pedestrians,
	Number Involved.		
Negative	39	24	13
Less than 0.05	4	5	2
0.05-0.09	6	5	1
0.10-0.14	7	5	4
0.15-0.20	15	6	3
More than 0.20	7	1	7
	78	46	30

Table 12 shows that 28 per cent of fatally injured drivers had a blood alcohol figure of 0.15 per cent or greater, while the corresponding proportion for passengers and pedestrians was 15 per cent and 33 per cent respectively.

The proportion of drivers is similar to that noted in 1965, namely 29 per cent but in regard to passengers and pedestrians the figures show a decrease on the 1965 proportions of 19 per cent and 47 per cent respectively.

Voluntary Blood Alcohol Tests.

176 samples of blood were submitted by the Police Department and 3 by Local Government Authorities in connection with charges of "driving while under the influence of intoxicating liquor". These samples were taken from persons who, on being charged with such offence, had exercised the right provided by the Traffic Act to have a blood sample taken by a doctor and submitted for chemical analysis.

The Traffic Act states that if the alcohol content of the blood at the time of the alleged offence is 0.15 per cent or greater it shall be prima facie evidence that the accused was under the influence of intoxicating liquor at that time. The results of these analyses are set out in Table 13, the figure being the alcohol content of the blood at the time of the alleged offence, calculated as prescribed by the Blood Alcohol Test Regulations.

Table 13.

Alcohol, Per Cent.	No. of Cases.
Less than 0.15	21
0.15-0.20	73
0.21-0.25	61
0.26-0.30	17
More than 0.30	7
	179

From accused persons who pleaded not guilty, 92 samples of blood were sufficient in quantity to be analysed by two chemists, making a total of 271 analyses in connection with this work.

It was noted, as a matter of interest, that in 60 cases, i.e. 34 per cent of those who submitted blood for analysis, a plea of guilty was entered at the Court before the result of analysis was known.

In the majority of these cases however the blood alcohol figures was greater than 0.15 per cent, as shown in Table 14.

Table 14.

Alcohol, Per Cent.	No. of Cases.*
Less than 0.15	8
0.15-0.20	23
0.21-0.25	18
0.26-0.30	7
More than 0.30	4
	60

* Plea of guilty prior to analysis.

An examination of the times at which the offence of "drunken driving" occurred showed that the greatest number of offences occurred between 10 p.m. and 11 p.m. followed by a lesser number in the period 11 p.m. to midnight, then a lesser but fairly uniform number through the hourly periods from 5 p.m. to 10 p.m. and midnight to 1 a.m. The distribution of the time of occurrence of the offence is given in Table 15.

Table 15.

Time of Occurrence.	No. of Cases.
p.m.	
4-5	7
5-6	11
6-7	12
7-8	14
8-9	17
9-10	15
10-11	40
11-m.n.	21
a.m.	
m.n.-1	14
1-2	8
2-3	5
3 a.m.-4 p.m.	15
	179

In the latter part of 1966 amendments to the Traffic Act were proclaimed to provide for the taking of breath and/or blood samples under two categories, namely—

(1) persons driving under the influence of alcohol;

(2) accident—injury cases.

19 blood samples taken under category (1) have been included and discussed under the heading Voluntary Blood Alcohol Tests. The samples were submitted voluntarily by drivers who also had had a compulsory breath test.

13 blood samples were submitted by the Police Department under category (2) from drivers concerned in accidents causing injury. These samples were taken compulsorily from drivers who were not able to undergo a breath test or because breath analysing equipment was unavailable.

The results of these analyses are set out in Table 16.

Table 16.

Alcohol, Per Cent.	No. of Cases.
Less than 0.15	8
0.15-0.20	2
0.21-0.25	2
0.26-0.30	1
	13

A number of blood samples were also analysed for alcohol in investigations conducted by the Police Department to check Breathalyzer readings against blood alcohol concentrations.

Specimens from Patients.

147 samples were received under this classification. Approximately 40 samples of blood and 100 of urine together with a small number of gastric contents, hair and nails were analysed in connection with the medical examination of patients for clinical purposes as distinct from industrial hygiene and toxicology. The varying analyses performed under this classification are detailed in Table 17.

Table 17.

Type of Analysis.	Number.
Alcohol	1
Amphetamine	5
Arsenic	14
Barbiturate	16
Benzene hexachloride	1
Carbon monoxide	3
Copper	12
Dieldrin	5
General examination	4
Iron	5
Lead	52
Organic phosphate	1
Phenothiazine derivatives	1
Thallium	1
Zinc	34

Animal Toxicology.

The number of samples received under the classification of animal toxicology was less than usual. From 8 animal post mortem cases, strychnine was detected in two cases, arsenic in one, and five were negative.

From 17 suspected poison baits strychnine was detected in three, cyanide in one, and 14 were negative.

Investigations into suspected fluorosis in dairy cattle were conducted by the Animal Health Branch of the Department of Agriculture, and 22 samples of urine were analysed for fluorine content.

As a check on the distribution of the poison during the mixing process, 26 samples of prepared dingo baits were submitted by the Vermin Branch of the Department of Agriculture and were analysed for strychnine.

Samples of chicken liver, fat and feed were analysed for the Poultry Branch of the department of Agriculture in connection with investigations into disease of young chickens. Although small concentrations of chlorinated pesticides were detected in the tissues, none were detected in the feed consumed by the chickens.

Industrial Hygiene.

183 samples were examined during the year in connection with industrial hygiene investigations.

150 of these were specimens of urine from workers exposed to suspected lead hazard, and were analysed in order to assist clinical diagnosis or as a "screening" to exclude the possibility of undue exposure.

Of these specimens, 126, or 84 per cent contained not more than 0.08 parts per million (milligram per litre) of lead (Pb), 11.3 per cent contained 0.09-0.15 part per million, 2.7 per cent contained 0.16-0.20 part per million and 2 per cent contained more than 0.20 part per million.

Other specimens of urine examined in connection with possible exposure to hazardous materials included analyses—

(1) for arsenic from pest control operators;
(2) for mercury from workers engaged in "amalgam" operations;
(3) for dieldrin from pest control operators and a worker handling dieldrin concentrates.

Samples of blood were also analysed for lead as an adjunct to the urine analysis in a number of cases, while other samples of blood were examined for carboxyhaemoglobin in an attempt to assess exposure to furnace gases.

Four inspections were carried out as a result of complaint of hazardous working conditions in the holds of cargo ships.

These were the result of spillage due to broken containers of Cyanogas (calcium cyanide), sodium metabisulphite and butyl xanthate, and a "chemical" odour due to an unidentified liquid of naphthalenic origin. "On the spot" assessments were made of the potential hazard and advice given as required on ventilation and other protective measures necessary to ensure safe working conditions.

Miscellaneous samples received for examination included liquids for analysis for T.D.I. (tolyl diisocyanate), a printing fluid for analysis for benzene and assessment of fire hazard, and a sample of water whose reported "explosion" was almost certainly caused by the addition of metallic sodium.

Pollution Surveys.

Swan River.—The regular surveys of the Swan River were continued in 1966 when 108 samples of river water from normal sampling points were collected and analysed for the Swan River Conservation Board and there were also two non-survey samples.

17 samples of trade effluents from specific factories were also examined as a check on their suitability for discharge into the river.

Leschenault Inlet, Bunbury.—Examinations for the Public Works Department were continued with the regular summer and winter pollution surveys of the water in the Leschenault Inlet at Bunbury, and 48 samples were collected and analysed in the surveys of February and August, 1966.

Maritime.—Eight samples suspected of being oil were received and examined. These were fluids alleged to have been discharged from ships into waters under the jurisdiction of the Fremantle Port Authority. Analysis was carried out in order to establish that they were in fact oil or similar substance.

Miscellaneous.

Pesticides.—132 samples classified as pesticides were received and examined during the year. The numbers and variety of the samples are listed in the following table:—

Pesticide.	No. of Samples.
Weedicide concentrates—	
2,4-D amine	16
2,4-D ester	30
2,4,5-T ester	9
Aldrin (concentrate)	9
Aldrin (diluted emulsion)	21
Dieldrin (solid)	11
Dieldrin (concentrate)	17
Dieldrin (diluted emulsion)	2
Chlordane (concentrate)	3
Malathion (concentrate)	2
Various	12

The samples of aldrin concentrate and diluted emulsion were examined for the Architectural Division, Public Works Department, in connection with "white ant" preventive treatment applied to a number of building projects. Frequent sampling was carried out as a check to specification of materials being used for treatment purposes. Several samples of dieldrin were also used for this purpose and similarly examined.

Samples of technical dieldrin and of dieldrin and chlordane concentrates were analysed for conformity to specifications required variously by the Agriculture Protection Board and Biological Services Division of the Department of Agriculture.

The marked increase in the number of 2,4-D type weedicides received in 1965 was maintained in 1966. 55 samples were received from the Weed Control Branch at regular intervals during the spraying season and were analysed as a check on the quality of the concentrates.

Miscellaneous pesticides received for examination included malathion concentrates for use in fruit fly control, a large unlabelled drum of fluid which was identified as D.D.T. 25 per cent concentrate, an alleged aldrin concentrate which proved to be dieldrin, and an organic phosphate "drench" thought to have been responsible for the death of several animals.

Criminal Cases.

Following five separate complaints of illness of persons, samples of coffee, curry and rice, tea and wines were examined for possible poisons with negative results. One sample of prepared coffee seized by an Inspector of the Liquor Inspection Branch was found to contain 4.5 per cent w/w of alcohol.

Samples of drugs and medicines were examined in two separate cases of alleged poisoning. In one case xylene was present in a jar containing medicinal capsules.

23 samples of wheat were analysed in an effort to provide information concerning thefts from farms. "Ceresan" was detected in all samples. A travelling rug and a plastic bag were examined in connection with a stealing offence. Paint flakes and other exhibits were examined in connection with accidents, one fatal, involving motor vehicles. A sample of diesel fuel was found to have been adulterated with sugar.

A variety of exhibits, including charred cloth, the remains of a flare, a tar brush, a candle and pieces of cotton wool were examined in endeavours to ascertain the cause of several fires.

General.

70 samples of detergents were submitted by the Government Tender Board for consideration as to those most suitable for use in Government Institutions. These varied from the relatively simple synthetic detergents to composite soap powders, laundry adjuncts, liquid soap type cleaners with and without deodorant properties, steam,-cleaning compounds, solvent type degreasers, and detergent preparations for highly specialised uses.

Regular testing of "high altitude" oxygen for the Directorate of Quality Control of the Department of Air was continued for the first 8 months of the year and 22 cylinders of this oxygen were received and analysed for conformity with R.A.A.F. specifications. As a result of change in policy in regard to specifications and testing, no further samples were submitted after August 1966.

Only 11 samples of "building materials" were received during 1966 for fire resistance tests to assist in determining their suitability for use in public buildings.

3 samples of upper leather and 5 of sole leather were analysed as a check against compliance with specifications required for Commonwealth contracts.

33 samples of tallow were analysed to check their quality against trade requirements, and 8 samples of mixed organic solvents used in an industrial extraction process were examined by gas chromatography as a check against alteration of their relative proportions after usage.

Prior to the introduction of "breath tests" for alcohol under amendments to the Traffic Act, five Breathalyzers were submitted by the Police Department for calibration and certification that they were in satisfactory working order, and 12 sets of blood alcohol collection kits, as distributed to Police Stations throughout the State, were tested in order to establish the absence of alcohol in the equipment used to obtain blood samples for subsequent alcohol determination.

6 samples of fireworks were examined to establish the absence of arsenic in the pyrotechnic compositions, and four samples of "prilled" ammonium nitrate were submitted for determination of organic matter.

4 samples of suspected ambergris were received during the year but only one was a genuine ambergris, of low grade.

22 samples of sandalwood oil were examined by infra-red spectroscopy in order to assist the identification and comparison of imported and local products prepared by different processes.

97 samples of fat from beef cattle intended for export were received for analysis for dioxathion (Delnav) content. After 49 samples were found to be well below the statutory maximum concentration of one part per million, the routine analysis was discontinued, and an experiment was commenced late in the year to determine the variation in dioxathion content of the fat during prolonged storage in "deep-freeze", approximately —10° C.

16 samples of linseed were analysed for oil content and for iodine value of the extracted oil in connection with variety selection trials conducted by the Department of Agriculture, and 7 samples of cotton seed from crops treated with pesticides were analysed to ascertain the proportions of these pesticides present in the outer "lint" and in the tissue of the seeds.

A further two investigations were carried out by the Department of Agriculture to check the extent and effectiveness of ground spraying with a "mister" fitted with different nozzles. The spray, containing a dye, was deposited on test plates placed on the ground at pre-arranged intervals. 298 test plates were examined for dye deposited on the surface and the application of the spray in terms of gallons per acre calculated.

Consequent upon increasing interest in toxicity to stock of natural plants, 162 samples of plant material were submitted by the Botanist's Branch of the Department of Agriculture for analysis for fluoroacetic acid and its derivatives.

Miscellaneous samples received and examined during the year included floor polishes and floor cleaners submitted for testing by the Tender Board, local anaesthetics for evidence of deterioration, sea-weeds for determination of agar content, mine airs for "oxygen depletion", various powders, etc., for identification, a sample of disinfectant involved in a minor "explosion" in a sterilizer, overalls for flameproofness tests, and waste effluents from a laundry.

The normal enquiries for technical information and advice were received during the year and expert evidence was tendered as required by officers of the Division in connection with their official duties.

Conferences and Talks.

Mr. N. R. Houghton attended the meeting of the Food Analysts Sub-Committee of the National Health and Medical Research Council in Brisbane in July.

Mr. F. E. Uren attended (a) the Annual Conference of Scientific Officers Engaged in the Field of Industrial Hygiene held in Sydney in May and following that (b) a symposium on the Identification and Estimation of Traces of Volatile Compounds, at Mt. Buffalo.

Mr. F. E. Uren gave talks on "Forensic Chemistry" to the Scarborough Rotary Club and the Gosnells Salvation Army Men's Fellowship.

FUEL TECHNOLOGY DIVISION.

The Division had 174 registrations of investigations or samples assigned to it in the year. The National Coal Research Advisory Committee project, viz. "Investigation of the mechanism of reaction of solid carbon with metallic oxides in connection with the direct reduction of ores with coal" Lab. No. 11926/65, has been continued. Our progress with the investigation was received favourably by the Committee and the enabling grant of $10,000 was continued for another year. There have been discussions with the Committee on the determination of the reactivity of Collie coal and its char with sulphur and preliminary work has been done on this with a view to undertaking the investigation during 1967. This is related to Japanese interest in Collie coal for carbon disulphide manufacture. Experimental shipments of coal to Japan have been made by one mining company for this and other purposes. One shipment was overseen by us. The coal did not heat in transit; still less was there danger of spontaneous combustion so often predicted for Collie coal in ship holds. The favourable experience confirmed a long held opinion that the high moisture content of Collie coal must safeguard it against spontaneous heating and combustion when stored in bulk in conditions which prevent evaporation and free ventilation.

The Fuel Technologist continues to serve as State Representative on the National Coal Research Advisory Committee of which there have been three meetings during the year. He has also served as Mines representative on the Air Pollution Control Council which has met three times during the year.

The Division's Grade 1. Chemist and Research Officer has served on the Scientific Advisory Committee provided for under the Clean Air Act. He has attended nine meetings of this body and has assisted it in various other ways as a consultant well versed in matters of air pollution.

The effective staff of the Division has comprised the Chief of the Division, one Grade 1 Chemist and Research Office, one Grade III Chemist and Research Officer, one Laboratory Technician, one Laboratory Assistant. A Chemist and Research Officer Grade III borrowed from the Division in 1965 was not restored during the year. The effective performance of the wide variety of activities of the Division detailed in this report has only been achieved by the exercise of industry, ingenuity and operation of staff above the levels of their grades. This has been recognised in the activities of the Laboratory Technician and Assistant by upgradings with some degree of retrospectivity during the year.

Detail of work done is set out in ensuing sections of the report. This includes the National Coal Research Advisory Committee's Metal Oxides Reduction assignment 11926/65 as reported to the end of 1966 and a summary of work overstanding on Fireplace Efficiency and Design (11195/59).

Table 18.

Fuel Technology Division.

	Departmental	Hospitals	Metropolitan Water Supply	Mines Department	Public Health Department	Public Pay	Public Works Department	State Housing Commission	Total
Atmospheric pollution	66	....	....	....	....	1	....	....	67
Boiler corrosion	....	....	....	....	....	....	10	....	10
Coal and coal products	8	....	....	....	....	58	....	....	66
Fuel	....	....	....	....	....	5	2	....	7
Miscellaneous	4	2	2	2	7	6	....	1	24
Total	78	2	2	2	7	70	12	1	174

Table 19.

South-West Coals.

Most of these samples were obtained from the working faces at the Collie coal mines. One of the samples was obtained by drilling in the Collie coal basin and one was obtained by drilling in another area of the south-west of Western Australia. These two drilling samples are reported on the arbitrarily selected moisture basis of 20 per cent.

Lab. No.	1806	2462	5481–5483	5657*	8307	8308–8310	10231–10237	10449	10450	10451	10452	15282†
Source	Muja	Muja	Collie	Muja	Muja	Muja	Muja	Collie	Collie	Muja	Muja	South-West
	per cent.											
Analysis—												
Moisture	25·7	25·0	21·9	20·0	20·8	23·1	22·9	26·9	23·4	23·5	25·0	20·0
Ash	2·0	2·2	4·7	6·9	6·0	2·7	2·5	3·0	6·8	1·2	2·5	7·9
Volatile matter	27·5	29·2	28·6	33·8	29·5	29·7	30·1	27·6	23·5	29·3	30·5	38·8
Fixed carbon	44·8	43·6	44·8	39·3	43·7	44·5	44·5	42·5	46·3	46·0	42·0	33·3
	100·0	100·0	100·0	100·0	100·0	100·0	100·0	100·0	100·0	100·0	100·0	100·0
Sulphur	0·3	0·4	....	....	1·95	0·7	0·6	0·3	0·2	0·2	1·1	0·9
	Btu per lb.											
Calorific value—												
As analysed basis	9250	9320	9280	8580	9240	9470	9500	8920	8980	9650	9290	9210
Dry, ash-free basis	12790	12800	12640	11740	12620	12760	12730	12720	12860	12820	12810	12770

* From drilling in Muja area. † From drilling in South-West of W.A.

Coal Samples.

South-West Area.—Various samples of coal from Collie were collected from the working faces by Departmental officers or were submitted by the mining companies. The samples were all typical of the seams being worked. One unusual sample was submitted by a company which encountered the coal when drilling for water. This coal is different in some respects from Collie coal. The analyses are listed in Table 19.

North-West Area.—A large number of samples was submitted by companies which encountered the coal during drilling operations. The coal was variable in quality and generally of high ash content. Beneficiation tests were made in some cases to assess the potential of the coal for upgrading processes. The analyses are listed in Table 20.

Table 20.

North-West Coals.

These are analyses of coal samples obtained by drilling in the Kimberley area of Western Australia. The analyses are reported on the arbitrarily selected basis of 20 per cent moisture for comparison purposes.

Lab. No.	12259	15265	7821–7831	8925–8929	9763–9769
	per cent	per cent	per cent	per cent	per cent
Analysis—					
Moisture	20·0	20·0	20·0	20·0	20·0
Ash	40·2	21·1	19·9	17·7	48·6
Volatile matter	16·9	19·1	27·8	28·3	18·8
Fixed carbon	22·9	39·8	32·3	34·0	12·6
	100·0	100·0	100·0	100·0	100·0
Calorific value—	Btu per lb.	Btu per lb.	Btu per lb.	Btu per lb.	Btu per lb.
20 per cent moisture basis	5190	8460	8120	8440	....
Dry, ash-free basis	13050	14370	13510	13550	....

Laboratory beneficiation tests were made on samples 8925-8929 by separation at specific gravity 1.45.

Fraction.	Weight. Per Cent.	Ash. Per Cent.
Sp. gr. below 1.45	70.5	9.9
Sp. gr. above 1.45	29.5	43.9

Applied Fuel Technology

1. A shipment of Collie coal to Japan afforded an opportunity to gain information on the behaviour of coal held in bulk in the restricted conditions of a ship's hold which are such that air has limited access to the coal so that it cannot dry off and lose intrinsic moisture as it does when freely stored in an exposed pile. The coal was a good sample from the Muja seam containing only 2.5 per cent of ash and 24.4 per cent of water as loaded. It was in the lower forehold of a Japanese freighter, covered over directly with polythene sheet and finally closed over by the hold covers. Three thermocouples were inserted into the coal and an air sampling pipe lead up to the foredeck. The loading was inspected at Bunbury. The ship reached Fremantle four days later and was again visited. There had been no rise in coal temperature. The air from over the coal had the following analysis: CO_2 - 0.4 per cent; O_2 - 15.3 per cent; CO - 0.3 per cent; CH_4 - 0.2 per cent; N_2 - 83.8 per cent. This analysis showed that oxygen from the air had been taken up by coal without release of carbon oxides, as is commonly found with coals at ambient temperatures. The point was demonstrated in the laboratory by storing Collie coal in a closed polythene bag. Over the course of ten days the coal absorbed all but 1 per cent of the oxygen from the air in the bag but released only about 2 per cent of carbon dioxide.

The shipment of coal reached Japan after a five week voyage. No heating was recorded on the voyage and the consignment was unloaded in good condition and without trouble from hot or fiery coal.

2. Lucerne drying was discussed in the 1965 Annual Report and a comment made that the drier which we had designed could be improved by adding a down-stream fairing and baffles to the main fan to give the air directional flow straight down the underbed tunnel of the drier. This has now been done and the desired result obtained. The performance of the drier has been much improved and its oil consumption per ton of product lowered. State demands for lucerne meal as a poultry food supplement are now being provided in substitution for former Eastern States supplies.

3. A storage water heater fired by kerosine was tested. Its capacity was 44 gallons against a nominated capacity of 50 gallons. The fuel consumption was about 1 lb of kerosine per hour which gave a heating time of 3 hrs. from cold at 80° F to hot at 170° F and a recovery rate, after drawing off hot water, of 15 gallons of 170° F water per hour. The heating efficiency was 68 per cent.

4. A fireplace of metal construction with a restricted flue and designed to stand inside standard log-burning brick fireplaces was tested between 1959 and 1960. The results have now been collated and reported. The fireplace was tested free standing under a metal flue which could be varied in height and cross-sectional area. In use the fire is designed so that it can be installed

with its flue projecting through a baffle up into the chimney of brick fireplaces. The purpose of the baffle is to prevent hot air from the metal back and sides of the fireplace escaping up the brick chimney of the fireplace and to direct it instead into the living space which the fire is to heat. The front of the fire is open and presents the ordinary appearance of an open fire. The body of the fire has a stream-lined form of entry and fairing to a flue of 9 in. x 3 in. cross section which is restrictable by a flap damper. Round flues may also be used.

The average room heating efficiency of the fire using log wood as fuel was 38 per cent with a lowest figure of 29 per cent and highest of 50 per cent. On coal the fire gave a 50 per cent heating efficiency without much variation. This latter figure is equal to that obtained from flued oil-fired room heaters.

The volume of chimney gases as measured either by pitot tube or by a half venturi inserted into the flue pipe was between 3,000 and 4,000 cubic feet at N.T.P. per hour implying that the volume of replacement air drawn into a room by the fire is within these limits, contrasting with the volume removed by most open fires of up to 20,000 cubic feet an hour.

A major factor in living room comfort is the limitation of the rate of indrawing into the room of cold outside air in winter at 50° F or less and requiring heating to acceptable comfort level temperatures of above 70° F. A reduction of indrawn volume from 20,000 to 4,000 cubic feet an hour and a converse increase in heating efficiency from 15 per cent for ordinary open fires to the 40 per cent figure found for these metal fires represents an overall reduction in fuel consumption of 80 per cent in respect of incoming air heating.

A main purpose of the investigation was to determine a suitable ratio of flue area to open front area of the fires tested and suitable heights and shapes of the flues. A flue area between one sixth and one seventh of the open frontal area of the fires was found sufficient to maintain an inward draught through the open front and thus preclude any escape of smoke into the room. For a fire with an approximate 1.0 sq. ft. open front a 5 inch diameter round flue pipe 12 feet in height maintained the desired conditions of inward draught through the front of the fire, though only marginally. A 5½ in. diameter flue would have been more satisfactory as formulated below.

Flues could also be shaped or bent back or sideways at 45° and return to the vertical so that they could pass through and up the outside of a wall. Such changes of direction caused no interruption in the free flow in flues or their effectiveness in smoke withdrawal.

A formula was finally reached relating an air withdrawal rate through the open front of a fire based on two complete changes of air per hour from a room of volume V c.ft. and a desirable air inward velocity through the open front of the fire of 60 f.p.m. and a 1 : 6 ratio between flue area in round flues and open front of the fire.

Area of open fire front $= V/1800$ sq. ft. $= A$ sq. ft.

Diameter of flue $= 5.5\sqrt{A}$ in.

Air Pollution.

The deliberations of the Scientific Advisory Committee and the Air Pollution Control Council established under the Clean Air Act have consumed much time. So far neither body has succeeded in framing regulations suited to both the strictures of the Clean Air Act and the low incidence of air pollution in the State.

Measurements of fluorides emitted from brickworks chimneys were made. The chimneys served tunnel kilns firing bricks made from Cardup Shale. The fluoride content of the chimney gases was between 100 and 200 ppm. to be compared with the sulphur dioxide content of 400 ppm. The permissible ground level limits for sulphur dioxide are only one tenth of the figure permitted for hydrogen fluoride. A chimney height satisfactory for sulphur dioxide dissipation will thus be more than adequate for the acceptable dissipation of hydrogen fluoride. Furthermore calculations of brickworks chimney heights showed that the high temperature and large volume of the chimney gases give them an exceptionally high plume rise which should secure adequate dissipation if the chimney delivers above the region of roof down-eddies.

Nevertheless as brickworks constitute a general source of pollution from dust in materials handling and a concentration of chimney gases every effort should be made to prevent surrounding them with residential developments which, in common experience, leads to unresolvable friction between the industry and its neighbours.

Odour from Subiaco Sewage Works has been the occasion of one committee meeting with the officers in charge of the plant. The odour destruction burner continues to operate satisfactorily but measurements made on it and reported showed that it was operating at over 600° C. instead of the 300° C. temperature at which it was calculated to operate. It is treating 9,000 c.ft. per hour. It can therefore either treat more foul air or treat the same amount with less digester gas. Attention to these quantities is of value as the present intention is to instal other burners to destroy odour in foul vented air.

Work was also done on sweetening of foul air by active iron oxide and wood charcoal. The combination removes odour completely. Iron oxide by itself acts only as an odour improver by catalytic removal of hydrogen sulphide which it can do for an indefinite period whereas the wood charcoal has only a limited capacity as a final sweetener. In doing so it takes up volatile sulphur compounds which can be recovered by steam distillation. The iron oxide will, in the main, remove hydrogen sulphide only, thereby, however, reducing in considerable degree the offensiveness of the odour.

Domestic and institutional incinerators received some consideration. The major problem with them is incineration of waste paper and millboard. If they are fitted with exhaust fans and cyclone incineration can be controlled as already shown in one installation to our own design. It is possible that a low pressure loss cyclone by itself would exercise sufficient control. The preferable cure however lies in consigning suitable waste to paper recovery salvage.

Dust Deposition.—Gauges in residential and industrial areas in the inner Metropolitan Area have been regularly attended during the year. One residential site at Swanbourne was deleted and one new site was added by setting up a gauge in the grounds of these Laboratories close to Adelaide Terrace. It is expected that this gauge will indicate the effect of heavy road traffic on dust deposition, Table 21.

Table 21.
Dust Deposition 1966.

Test Position	Rate of Deposition. Tons per Square Mile per Year					
	Summer			Winter		
	Max.	Av.	Min.	Max.	Av.	Min.
Industrial—						
East Perth	430	320	185	610	330	200
Rivervale	170	120	100	190	120	85
Main thoroughfare						
Laboratories	440 (a)	240	80	90	90	80
Residential—						
Redcliffe	100	70	55	70	50	30
Wembley	65	40	30	55	40	20
Swanbourne	65	40	20	70	40	25

(*a*) This sample was probably contaminated with deposit from bore water used for watering and as a result the maximum and average figures reported for this site are too high.

The average loss on ignition of samples is about 50 per cent indicating considerable organic matter which is confirmed by microscopic examination. The major inorganic constituent is always silica with a little iron oxide and usually coke or carbon of some kind. The samples from industrial sites reflect the nature of the adjacent works in that the Rivervale sample always contains calcite and the East Perth sample always contains coal dust. The heavier depositions in these areas are a measure of the pollution caused over a limited area by a works of moderate size.

Dust and Sub-sieve Particle Size Analysis.

A bulk sample of silica flour was obtained in 1965 for our own use and as a source of samples for distribution to other laboratories for inter-comparison of size analyses by the variety of methods in use for particle size determinations.

So far seven laboratories have returned results from a total of six different types of apparatus covering wet cyclones, centrifugal air elutriation, X-ray photoelectric sedimentometer, sedimentation balance, a conductivity counter and a simple densitometer. The agreement between the various methods was excellent for some and for others fair with general confirmation of the two methods in use by us, an air elutriator and a photoelectric sedimentometer.

A United States laboratory sent us a sample of a limestone powder and its size analysis curve. We obtained concordant results by air elutriation but not with our photoelectric sedimentometer. The latter instrument uses settlement in liquids as the basis of measurement. Our present conclusion is that the limestone particles agglomerated to some extent in the water and kerosine used as suspension liquids and therefore gave a displacement of analysis towards the larger sizes. The co-operating United States laboratory has not as yet returned to us an analysis of the standard silica sand sent to them.

Dust in blast furnace gas was measured for an undertaking. The determination was a difficult one in saturated gas but a method was established whereby the works staff obtained a series of determinations which reassured them that the gas could be used in regenerative air blast heating.

Refractories.

A brick clay was substituted for an opinion on changing its normal bright terra-cotta burnt hue to a dark blue-brown. The clay was siliceous mixed with iron-rich clay nodules. The nodules fluxed when burnt to a sufficiently high temperature and produced blue-black iron spots and holes in the brick. The users stated that to get this dark, pockmarked semi-clinkered appearance the bricks were burnt at 1450°C. The normal clear terra-cotta was produced at 1250°C.

Our examination by refractoriness under load test showed that a hard red brick could be obtained by burning within the temperature range 1000-1100°C and the dark clinkered brick in the range 1200-1300°C. In the lower temperature range a brick of 6000—8000psi. crushing strength could be produced.

Experiments with various colouring agents showed that superficial spraying with a slurry of the iron oxide-gypsum product obtained by the reaction of lime with copperas gave the desired blue-black in the range 1000-1100°C.

The investigation should, if the client pursues the mater and takes further advice on kiln operation relative to temperature, result in major fuel oil savings. There is however an unfortunate tendency amongst operators in small industries to think that the laboratories only function analytically and are not capable of useful extra-mural work.

Miscellaneous.

Fireside tube deposits in oil fired hot water boilers continue to be a cause of concern to operators. The deposits are always of an acid iron sulphate and at first sight appear to be a product of condensed sulphur trioxide attack on the steel boiler tubes. But the tube metal and end plates of the boiler do not seem to be attacked and tend in general to show their original mill scale. Test pieces were inserted in one boiler and left there for a period of 3 months. Over this period they accumulated a covering of the usual acid iron sulphate but when this was brushed off the test pieces showed no signs of attack. They had not lost in weight and the metal was covered by the original mill scale. A lead oxide type corrosion inhibitive oil additive was used in the oil over the period of the test. Traces of lead were found in tube deposits.

A tin-bearing gravel was submitted for an opinion on beneficiation without the use of water. The sample was ground in our ball mill for a short period sufficient only to break up agglomerates. It was then sieved and the concentration of tin determined in each size fraction. This showed that the treatment would give the following distribution of tin according to analyses made in the Mineral Division.

Fraction B.S.S. mesh	Per cent of whole sample	Tin, Sn	
		Per cent of fraction	Per cent of total tin
+ 8	20	N.D.	N.D.
— 8 + 18	18	0·130	39
— 18 + 100	36	0·093	54
— 100	26	0·015	7

N.D.—Not determined.

It was apparent that tin was for the most part contained in the minus 8 plus 100 mesh screenings and isolation of material of that size would reduce the bulk of material for further treatment by about half, with very little loss of tin.

Conferences, Talks.

Mr. L. Brennan attended a Fuel Conference organised by the Institute of Fuel in Newcastle in October.

INDUSTRIAL CHEMISTRY DIVISION.

Introduction.

The year's work continued to reflect in general character the industrial progress of the State. Although the total number of samples received was only 122, several of these entailed a fair amount of work. There was in addition the still-growing consultative practice which has more than doubled over the past three years. As in previous years research and investigational work was undertaken when and as the staff were free from other duties.

Staff.

Mr. P. J. J. Labuschagne, Chemist and Research Officer Grade III, resigned on 18th November.

Mr. H. Schuller was appointed temporary laboratory assistant from 1st August.

Mr. A. Reid continued to lecture two evenings per week on Reinforced Plastics at Carlisle Technical School.

Classification of Work.

The year's work may be classified—

(1) routine—
  (a) Building Materials;
  (b) Plastics;
  (c) Miscellaneous;

(2) assistance to Industry;

(3) investigational;

(4) consultative.

Table 22.

Industrial Chemistry Division.

	Departmental	Civil Aviation Department	Industrial Development	Metropolitan Water Supply	Mines Department	Public Pay	Public Works Department	Total
Building materials	....	....	1	....	....	6	13	20
Minerals	61	....	....	....	....	1	....	62
Plastics	....	....	3	1	3	....	7	14
Miscellaneous	....	7	....	....	....	8	11	26
Total	61	7	4	1	3	15	31	122

(1) Routine.

(a) Building Materials.—Twenty samples of building materials were examined during the year, chiefly for the Public Works Department. Six samples were examined for private contractors mainly to ascertain causes of failure in service, as a basis for advice on remedial and preventive measures.

Nine samples of mastic jointing and caulking compounds were examined for heat and ultra-violet light resistant properties. Those based on the polysulphide resins were found to be superior to the oil-based putty type.

There was the usual crop of stains on fibrous plaster walls and ceilings, for diagnosis as to cause, and for advice as to appropriate remedies. Cases of flush-joint staining were, as usual, common. One case of random staining in a deep purple colour was identified as a sulphide stain which could be bleached by a hydrogen peroxide-sodium versenate mixture. An interesting case was the staining of the ceiling of a hospital lounge by tobacco smoke carried upwards by convection currents from wall radiators; remedial measures were suggested.

Failure of a ceramic tiled exterior wall was investigated for a local contractor and a sample of special ceramic tile fixing cement was found to be satisfactory. Failure was attributed to causes other than the cement, or the application technique.

Two samples of P.V.A. emulsion paint were examined for relative quality. Although one paint had a higher pigment content, because of greater fineness of grind of the pigment the paint with the lower pigment content had a greater covering power.

A sample of bitumen-based roof coating was examined for suitability for use on roofs subject to extreme environmental conditions, and was found to be unsuitable because of its poor ultra-violet light resistance.

Three samples of chalkboard ("blackboards" for school class rooms) were compared for suitability. Tests included durability of surface, ease of writing and erasure, and visibility and contrast. One brand had some undesirable qualities, and recommendations were made to overcome these.

Two samples of terra-cotta floor tiles were compared for abrasion resistance, water absorption and dirt retention. In the absence of standard abrasion testing equipment, apparatus was improvised to give a comparison.

(b) Plastics.—Fourteen samples of plastics were examined during the year.

Three samples of foamed polyurethane were examined for effective buoyancy, water absorption and mechanical properties for the Harbour and Light Department. No significant variation was found in the three brands of foam submitted.

Three samples of plastic were identified for the Chief Inspector of Explosives in connection with a hospital sterilizer explosion. It was concluded that they were unlikely to have initiated or contributed to the explosion.

Advice was given to the Occupational Health section of the Public Health Department on the moulding of protective ear-plugs in silicone elastomers.

An unusual pink stain on vinyl fabric was found, after a literature search, to be due to a fungus of the penicillium family. The stain cannot easily be removed, but its occurrence can be prevented by pre-treatment with an isoquinoline naphthenate type of fungicide.

A P.V.C. water pipe which failed under test was examined for compliance with specifications. As the pipe complied with the standards, it was concluded that the failure was due to service conditions in testing.

Sample of polypropylene hinges and clips, fibre glass insect screen and P.V.C. strip were examined for a local manufacturer at the request of the Department of Industrial Development. The Department was advised of improvements which the manufacturer might make.

A persistent odour identified as styrene monomer in the reinforced plastic water tank of Harbour and Light Department's new launch was traced to faulty curing of the plastic and undercuring of the resin. Replacement of the tank was recommended and the faulty tank was steamed out to make it possible to use it until a new tank could be fitted.

The Division made recommendations as to the epoxy resins to be used and the technique to be followed in making anode holders for the cathodic protection of piers in North-West harbours; the recommendations followed some experimental check work. A recommendation for the filament winding of pipe to contain the anode holders was submitted to the Electrical Branch P.W.D. and samples of pipe wound to the recommendation were tested for impact strength, water absorption, angle of wind, glass/resin ratio and soundness. Results were satisfactory. A full report on this work is in draft.

(c) Miscellaneous.—Samples of friable guano alteration products from the Mineral Division were impregnated with a clear polyester resin using a technique developed experimentally. Thin sections of the impregnated samples were subsequently prepared for microscopic study. Recently developed polyester resins practically transparent and of high clarity are suited to this type of work.

Failure of cotton terylene mixture wind socks at aerodromes in Western Australia was found to be due to deterioration of the cotton, the terylene remaining sound. There was evidence to indicate that the failure of the cotton was very probably due to faulty application of the sterilizer in which the wind socks are dipped.

(2) Assistance to Industry.

Five samples of wax were examined on behalf of an intending wax refiner who was advised on refining techniques, equipment and the general market potential for his intended products.

A large sample of poultry offal was processed by solvent extraction to remove fat and water. The glass lined kettle in the unit process plant was modified, and used to simulate the action of a four stage counter current extraction unit. The fifty litre distillation unit was rearranged so that the fractionating column could be extended to make it equivalent to twenty theoretical plates and to enable the reflux ratio to be increased. This step was necessary to give a high percentage recovery of high grade distillate from the extraction unit liquor. The sample was processed on behalf of a local firm interested in preparing a protein-rich meal from poultry offal. It is intended to incorporate the meal in pelletised stock food for broiler chicken production.

A chemical manufacturer was given the necessary information e.g. volume, liquid depth, insulation thickness and steam consumption, to enable him to construct a reaction vessel for the formation and crystallisation of his product. Details of the process and final product are confidential.

(3) Investigational.

Work on the manufacture of lithium salts from local ores continued with the sponsorship of a large Company. Attention was transferred from petalite to spodumene as a raw material. A new tube furnace was constructed and trials are in progress to establish optimum conditions.

Work on the painting of Karri timber was continued. Both quarter sawn and back sawn timbers at kiln dry moisture (12 per cent) and green (40 per cent) were painted. Primers were varied both in vehicle and in pigment. Undercoats were however not varied significantly. Top coats included alkyds, acrylics and urethanes. To cover these variables approximately one thousand five hundred test panels were prepared. Timber moisture determinations and wet paint film thickness measurements were carried out during the painting.

Preliminary investigations were made into the possibility of manufacturing furfural by acid hydrolysis of karri sawdust. Because of the relatively high furfural content of karri, and the concentration of the karri milling operations in the

Manjimup area, it is believed that the potential exists for an industry in this area, provided a suitable process can be developed and applied.

Work was continued at intervals on the construction of a portable slip measuring machine. This has been completed and awaits testing. Interpretation of results and their significance are still in dispute but could be resolved by extensive checks on a variety of surfaces in a variety of conditions.

(4) Consultative.

The Division has come to be known over the last few years as a source of information on technical matters particularly relating to industry and 1966 saw a continuing and apparently increasing volume of queries.

Broadly these could be classified as—

(a) sources of raw materials;

(b) specifications relating to raw materials and finished products;

(c) manufacturing processes;

(d) testing and test evaluation;

(e) potential markets for new products and new markets for old.

Professional ethics forbid the disclosure of these enquiries in most cases but a few generalities are possible.

Building materials in the broadest sense were the basis of the greatest number of enquiries, which in the main related either to new products or to those which had failed in service.

Plastics were a frequent source of questions. The local plastics industry continued to expand bringing with it numerous problems, particularly on properties and on testing procedures. A testing laboratory devoted entirely to plastics is overdue in this State and local industry is suffering through its absence. Fortunately there are indications that the situation may be remeded in 1967. P.V.C. occasioned more queries than any, with polyurethane, polyesters ("fibre-glass" plastics so called), epoxies and nylon following in that order. The newer acetals, polycarbonates and A.B.S. were a source of much interest.

Advice given on manufacturing methods and on the acquisition of raw materials and machinery have resulted in some smaller industries "getting off the ground".

Conferences and Talks.

Messrs. Reid, Douglas and Chafin attended a Symposium on Protective Coatings arranged jointly by the Oil and Colour Chemists' Association and the Corrosion Association, in Perth.

Mr. H. Douglas gave a talk to the Institute of Metals on 'The use of polystyrene in foundry practice.'

MINERAL, MINERAL TECHNOLOGY AND GEOCHEMISTRY DIVISION.

General.

With a reduction in the number of samples received in connection with a research programme on the geochemistry of the Golden Mile the total number of samples received during 1966 was about 25 per cent less than the previous year. The samples handled (3839) were nevertheless considerably in excess of the average for the previous five years.

The main sources of the samples were:—

General Public (free)	1757
General Public (pay)	1154
Geological Survey Branch	316
Departmental	300
Mines Dept. Branches (other than Geological Survey)	167

In addition to the Mines Department and its Branches, ten Government departments or instrumentalities submitted samples for examination.

Staff.

Messrs, R. Everett and A. G. Thomas joined the Division as Technicians towards the end of the year. The vacancy for a Mineralogist and Research Officer was not filled, but an additional Technician, Mr. K. Renton was taken on in a temporary capacity pending the filling of the professional position.

Mr. I. Twaddle resigned from his position as Technician in March.

Table 23.
Mineral Division.

	Public Pay	Public Free	Departmental	Mines Department	Public Works Department	Public Health Department	Main Roads Department	Department of Labour	Department of Native Welfare	Metropolitan Water Supply Sewage and Drainage Board	Department of Industrial Development	Department of Fisheries and Fauna	Department of Works	Postmaster General	Total
Burnt lime	32	....	....	....	....	....	....	....	....	....	....	....	....	....	32
Clay	41	4	....	1	12	....	....	....	....	....	1	....	....	....	59
Concrete	34	1	5	....	10	....	8	....	....	9	....	....	7	....	74
Dust	1	....	58	....	....	10	....	30	....	....	....	....	....	4	103
Metals and alloys	23	....	....	....	2	....	18	....	....	....	....	....	....	....	43
Mineral identifications	65	636	212	21	....	....	....	....	2	....	....	1	....	....	937
Minerals and ores—															
Arsenic	....	409	....	....	....	....	....	....	....	....	....	....	....	....	409
Copper	39	84	2	4	....	....	....	....	....	....	....	....	....	....	129
Gold ore	167	218	....	2	....	....	....	....	....	....	....	....	....	....	387
Gold tails	....	....	....	105	....	....	....	....	....	....	....	....	....	....	105
Gold umpires	....	....	....	29	....	....	....	....	....	....	....	....	....	....	29
Gypsum	19	5	....	....	....	....	4	....	....	....	....	....	....	....	28
Heavy sands	20	58	1	1	....	....	....	....	....	....	....	....	....	....	80
Iron	44	85	....	10	....	....	....	....	....	....	....	....	....	....	139
Lead	13	12	....	13	....	....	....	....	....	....	....	....	....	....	38
Limestone	24	5	....	2	....	....	....	....	....	....	....	....	....	....	31
Lithium	27	18	....	....	....	....	....	....	....	....	....	....	....	....	45
Manganese	7	33	1	....	....	....	....	....	....	....	....	....	....	....	41
Nickel	56	85	3	30	....	....	....	....	5	....	....	....	....	....	179
Phosphates	5	36	....	2	....	....	....	....	....	....	....	....	....	....	43
Silver	32	....	....	....	....	....	....	....	....	....	....	....	....	....	32
Tantalite	12	15	1	....	....	....	....	....	....	....	....	....	....	....	28
Tin	246	8	1	10	....	....	....	....	1	....	....	....	....	....	266
Titanium	28	4	3	....	....	....	....	....	1	....	....	....	....	....	36
Vanadium	20	....	9	....	....	....	....	....	....	....	....	....	....	....	29
Others	91	40	2	22	1	....	....	....	1	....	....	....	....	....	157
Miscellaneous investigations	74	1	1	3	12	....	....	....	....	6	....	....	....	....	97
Geochemical analyses	6	....	....	163	....	....	....	....	....	....	....	....	....	....	169
Complete analyses	28	....	1	65	....	....	....	....	....	....	....	....	....	....	94
Total	1,154	1,757	300	483	37	10	30	30	10	15	1	1	7	4	3,839

Messrs, L. Hodge and P. Bridge were members of a party that visited caves in the Jurien Bay area and returned with a suite of cave minerals including brushite and ardealite, two species previously unrecorded in the State.

Mr. M. B. Costello attended a meeting in Adelaide convened by the Geological Society of Australia and dealing with modern methods of rock analysis. Valuable contacts were made with specialists in this field and much useful information obtained on modern analytical techniques particularly as they apply to atomic absorption spectroscopy.

At the request of the National Association of Testing Authorities visits were made to the laboratories of three companies handling commercially metals and minerals. These visits were in connection with proposed registration of the laboratories by National Association of Testing Authorities; the assessments were carried out by Messrs. D. Burns and G. Payne.

Equipment.

The two main additions to the Division's equipment were an atomic absorption unit and a micro-hardness tester.

The atomic absorption unit was a Techtron AA-4 spectrophotometer with air-acetylene and nitrous oxide-acetylene burners. Hollow cathode tubes were obtained for estimation of the following elements: aluminium, antimony, bismuth, cadmium, cerium, chromium, cobalt, copper, gold, iron, lead, manganese, molybdenum, nickel, silver, tin, titanium, tungsten, vanadium, zinc and zirconium. Four special high intensity tubes are also available for aluminium, gold, nickel and silver determinations.

The simple possession of the appropriate tube does not mean that all problems associated with the determination of trace to minor amounts of the relevant element in minerals or rocks is automatically solved. Figures can only be accepted after considerable investigational work on each new element required, to determine optimum operating conditions and the effects, if any, of other elements present. Much of this work remains to be done.

A GKN micro-hardness tester was purchased for use in examination of opaque minerals. The unit has been attached to a standard polarising ore microscope (see also under Mineral Identifications).

Mineral Collections.

A total of 136 specimens were added during the year to the Mineral Division reference collection. All but 16 of these were from within the State, 11 being from overseas, 5 from interstate.

Specimens from outside Western Australia are limited as much as possible to species not represented from local sources. As the main purpose of the collection is for reference it should ideally contain at least one specimen of every known species.

Overseas specimens added to the collection in 1966 and which are the sole representatives of their species in the Divisional collection were colerainite from Chester County, Pennsylvania (obtained through the Smithsonian Institution), danburite from Mexico and chambersite from Lousiana (through Natural History Museum, California).

From interstate, specimens of davidite from Radium Hill, South Australia, and allanite and stillwellite from Mary Kathleen, Queensland, were added to the collection.

A selection from the minerals added from localities within Western Australia includes beryl (from Tantalite Hill, Mt. Day and Windsor Station), columbite (Marvel Loch, Mt. Marion, Lakeside Station, Windsor Station, 30 m NW Byro Homestead), tantalite (Melville), tapiolite (Mt. Edon), topaz (Payne's Find, Mt. Farmer), green tourmaline (Dalgaranga), bismutite (Melville), translucent cassiterite (Mt. Francisco), ilmenite (Cooke's Creek, Mt. Palmer), galena (Range Station, Murramunda Station), malachite crystals on graphite schist (Thaduna), chalcocite (Kumarina), chromite (Whim Creek), magnesiochromite (Ravensthorpe), nickeliferous goethite (Wingelline), cryptomelane (St. Ives), bindheimite (Range Station), baryte (Mia Mia Station, Yalgoo, Hill Springs Station), vivianite (Kennedy Range), corundum (Payne's Find, Yandeearra), silicified magnesite (Goongarrie), anthophyllite (20 m E of Coolgardie), prehnite and epidote (Beelyn Station), amethyst (Wyloo), halite (from 10160 ft. section of bore core), ettringite crystals in concrete, and portlandite (Victoria Reservoir dam) and the rare minerals perovskite and noonkanbahite from the Wolgidee Hills in the Kimberley.

A section of bore core from the Kambalda nickel deposit was donated by the Western Mining Corporation.

All requests from the general public for sets of mineral specimens as aids to prospecting could not be met due to temporary disorganisation of mineral stores by building alterations. However, sets were made available during the year for teaching purposes to the La Grange mission in the Kimberleys and to staff of State Schools at Melville, Wattle Grove and Jurien Bay.

In addition, 21 specimens representing five species of pegmatite minerals from 17 different Western Australian localities were made available to a post-graduate student at the University of New South Wales to assist in a research programme studying the nature and significance of inclusions in such minerals.

Building Materials.

1. *Concrete and Aggregates.*—A considerable amount of work was carried out on mortars, renders and concretes mainly with the object of determining the original mix.

It is unfortunate that only a very few cases are the original ingredients still available; in their absence, results are subject to so many assumptions as to be approximations of only limited value. Particularly is this so in the case of cement lime mortars where the "lime" can be of very variable nature.

Samples were received from both private and Government sources and included concrete and aggregate from the footing of a reservoir dam, mortars from concrete masonry paving, concrete from the Causeway, cement render from between concrete pillars and ornamental tiling and cement render from the lining of a private swimming pool thought to have been affected by the chlorine used to chlorinate the water. In the latter case the render was shown to be a very weak mix, a much more likely cause of its breakdown than the very low concentrations of chlorine in the water.

Of the individual ingredients of concretes and mortars, most work was done on aggregates, both coarse and fine, though a few cements were also examined. No work was done during the year on building limes in their relationship with mortars or renders.

A series of seven coarse aggregates were examined in detail for the Department of Works. This work included the determination of rock types, mineral content, degree of weathering, potential reactivity towards the alkali of cement and an assessment of mechanical strength and resistance to abrasion based on mineralogical and petrological examinations.

Sands were submitted for the usual tests (sizing, fines, organic matter, potential reactivity, mineral composition) and also for the presence or otherwise of sulphate, both soluble and insoluble, and of organic coatings which would render the sand difficulty wettable.

Complete chemical analyses were made of four cements, together with determination of specific surface area.

2. Bricks and Masonry.—Much of the work under this heading consisted in the identification and removal of stains on bricks and sandlime cement masonry.

Vanadium staining was the most common on burnt bricks and posed few problems in identification and removal. A number of white stains gave more trouble, their origin and nature being in some cases indeterminate.

An extremely thin discontinuous layer of white powdery material on a pressed brick gave an X-ray diffraction pattern suggesting aluminium silicate. No sulphates could be isolated from the powder. Two common forms of white staining on bricks are derived from either (a) sulphates originating from soluble sulphates in the clay or from sulphurous fumes in the kiln atmosphere or (b) migration to the surface of exceptionally fine-particled material in the clay resulting often from faulty drying techniques.

With the evidence available it was therefore concluded that the white stain in question was due to cause (b) above. No satisfactory chemical means of removing this type of stain was found.

Another white stain proved to be hydrous sodium carbonate. This is most unlikely to have originated from within the brick itself, a more likely origin being a detergent or compound used for cleaning the erected brickwork.

Red clay bricks in a newly erected building showed patches of white staining which was found to be essentially a silica gel. The wall had been cleaned down with acid and the gel had presumably originated with reaction of this acid with the mortar of the brickwork. It was completely removed by two washes with caustic soda solution.

A series of burnt bricks was submitted to determine if they were suitable for use in a power station stack exposed to acid gases. For use in this type of environment ASTM specifications lay down limits for the water absorption of the brick and its resistance to acid attack. The bricks tested did not meet requirements of this specification either as regards absorption or acid resistance.

Clays.

Clays were submitted from a number of localities for mineral identification and in some cases for detailed burning tests to assess their potential as ceramic or brick raw materials.

Eight samples from Ravensthorpe were examined at the request of Public Works Department. Bitumen was deteriorating due to apparent excessive movement of the underlying clay soil and information was required on the mineral composition of the soils, their cation exchange capacity and nature of soluble salt content.

There was considerable variation in the soil composition both as regards the nature of the clay minerals and their relative proportions. The non-clay minerals present were quartz and calcite while the clay fractions contained kaolinite, montmorillonite and illite.

A sample of red clay from Myrup was submitted through the Department of Industrial Development in connection with the possible establishment of a brickworks at Esperance. Though the material burnt to a good colour, no incipient vitrification occurred below 1300° C and at normal burning temperatures experimental briquettes were much too friable to suggest that the material would have any commercial value as a raw material for brickmaking.

A sample from black soil plains near Oobagooma in the West Kimberley, sent in by the Geological Survey, was found to consist of fine-grained quartz as the major constituent but with considerable proportions of the clay minerals kaolinite, montmorillonite and illite. It possessed no significant bentonitic properties.

About fifty samples of bentonitic clays were submitted by commercial interests for comparison by the Sadler gelling and the methylene blue absorption tests. Though these tests give results of some value for sorting samples in the field they are subject to a number of limitations.

One interfering factor is the not unlikely presence of gypsum. A pure bentonite should give a Sadler reading of 100 and should completely decolorize the methylene blue solution. Taking Wyoming bentonite as "pure", the following figures indicate the degree of error introduced by the presence of fine gypsum.

Bentonite	Gypsum	Sadler reading	Methylene blue test per cent colour remaining
per cent by weight			
100	0	100	nil
99·9	0·1	100	nil
99·0	1·0	99·5	trace
95·0	5·0	58	0·06
50·0	50·0	30	4·0

Dusts.

Examinations were made regularly of dust samples collected from deposition gauges in metropolitan and suburban areas. The nature and particle size of the deposit were determined.

Samples were submitted also from both Government and private sources. The dusts varied in health significance from the dangerous to the innocuous. In the former group, a sample taken in front of houses about 50 yards downwind from an open air sand blasting operation showed a concentration of 75 particles per ml of air, a significant proportion of which was quartz particles smaller than 5 microns in diameter.

Samples taken from nine areas in an iron foundry were examined for the Chief Inspector of Factories. Dust settling in a car park was found to be essentially gypsum while other samples submitted were found to be typical of what could be expected from heavy traffic on bitumen roads, or typical of what could be expected in an average household dust.

Minerals and Ores.

1. Beryl.—Only five samples representing commercial parcels were submitted for analysis during the year. All were of satisfactory commercial grade, ranging from 11.1 to 12.1 per cent BeO.

Specimens for identification were received from six different areas. One, from Wadgingarra, showed an unusual development of pyramid faces.

Information was supplied to a United Kingdom organisation to assist in their search for an alternative source of special grade of beryl previously obtained from a now dwindling source in S.W. Africa and a list was prepared showing producers during the past five years who could possibly supply the required 5 tons of beryl per year and samples were obtained where possible. As a result it is understood that beryl from Londonderry and possibly from the Cue area has been found to have the properties required for the special purpose.

The beryllium aluminium oxide, chysoberyl, was identified in a sample from the Poona area. Poona is one of the two localities in the State from which chrysoberyl has been recorded; it is possible that portion of the sample submitted was of gem quality. The specimen showed in one section a twinning effect by three superimposed prism faces.

2. Copper.—Copper assays were carried out on a variety of samples, with copper contents varying from a few parts per million up to 70 per cent and higher.

In many cases gold and silver were requested in addition to copper.

About a third of the samples assayed showed copper contents in excess of the minimum required (10 per cent) for ore used as a fertilizer additive, but a great many of these were unlikely to be representative of commercial deposits and many also contained a predominance of copper sulphide minerals.

The richest specimen was received from Kumarina, assaying 74.5 per cent copper and being composed predominantly of chalcocite with small blebs of chalcopyrite which were often surrounded by rims of bornite. Other high grade material came from Goongarrie (47.7 per cent), Narrina Downs (35.8 per cent), Mt. Brockman (36.7 and

29.8 per cent) and Ashburton Downs (34.7 per cent) with almost clean specimen material from Nullagine (a mixture of chalcocite, malachite and covellite), Burbidge (chalcocite and bornite) and Cue (a mixture of chrysocolla, malachite and cuprite).

In the samples assayed for gold and silver, the ratio of copper, to noble metals varied widely, though insufficient samples were examined to determine whether this ratio showed a regional trend as marked as it does in the case of lead minerals.

A sample from Warriedar, containing 4.2 per cent copper mainly as digenite, carried over 5½ oz silver per ton. Other samples assayed for their precious metal content included ore from Yeoh Hills (copper 14.5 per cent, silver 3 oz per ton, gold 5 dwt per ton), Dalgety Downs (copper 26.3 per cent, silver 1.4 oz, gold trace), Ashburton Downs (copper 34.7 per cent, silver 4 dwt, gold trace) and Glenflorrie (copper 9.48 per cent, silver 4 dwt, gold 0.5 dwt).

A large number of trace copper determinations were carried out by atomic absorption methods on geochemical samples, mainly for the Geological Survey.

3. Gold.—The noticeable increase in gold assays over the average of the past five years is mainly in the public free samples, the numbers of pay samples, and of State Battery tailings and umpire samples, being much the same as in previous years.

The big majority of samples submitted by prospectors, both professional and amateur, were naturally not of commercial grade. Against these, the odd sample showed figures suggestive of picked specimen material rather than ore. Among these were samples from Kangan Station (8 oz and 11 oz per ton), Goongarrie (36 oz) and an Avon location (70 oz).

Twenty-five samples were assayed to assist a University research programme in the Jeramungup area; five samples were supplied to a mining organisation for use as standards in the company's experimental work aimed at developing techniques for gold determinations by atomic absorption. The five standards covered a range from 4 to 78 parts per million, the actual figure being the mean of a great number of fire assay results.

Nine samples from Mulgabbie were assayed for gold and tellurium. Gold contents were all less than 6 dwt per ton and though no specific telluride minerals could be identified, chemical analyses showed the presence of from 10 to 200 parts of tellurium per million.

Gold assays were carried out on a range of products from the Wiluna area, including residues, slags and other abandoned metallurgical products, and on scheelite concentrates from abandoned gold mining dumps at Higginsville and elsewhere.

Arsenical ore from Mt. Rose in the West Kimberley area yielded about 10 per cent of its gold content in bench scale amalgamation tests. A slag from the Blue Spec mine, composed mainly of iron silicates, contained much free gold which did not respond to amalgamation due to a refractory coating on the gold particles.

A sample from the Kitchener Gold Mine at Bamboo Creek was submitted by the Government Geologist for examination and comment on its likely effect on amalgamation. The sample contained in order of abundance quartz, calcite, bindheimite, pyrite, galena, pyrrhotite and goethite with trace amounts of chalcopyrite, arsenopyrite, chalcocite and covellite. It is known that the more common arsenic and antimony minerals have a deleterious effect on amalgamation; it was shown that the far from common bindheimite (lead antimonate) caused much more flouring of mercury even than for example stibnite. Ore similar to the above could be expected to give trouble in cyanidation due to the solubility of the bindheimite in alkaline solutions.

4. Gypsum.—Most samples of gypsum were submitted for determination of their suitability for use in the plaster or cement industries.

An interesting end use proposed for a number of samples was the stabilizing of dusts in road making.

Two samples claimed to be rich in boron compounds gave no positive reaction for this element.

Three samples were assayed for a firm producing large tonnages of gypsum for export. The object was to try and explain discrepancies in analyses between different analysts using variations of the same method.

The assay method widely accepted by producers is essentially a technical one which has obvious limitations. Variations in analyses of products assaying between 90 and 100 per cent gypsum by this method are inevitable, depending on whether the gypsum is determined from the soluble calcium content or the soluble sulphate content and the extent to which precautions are taken to overcome interferences from impurities which may also contain lime and or sulphate. For umpire samples, or when figures of high accuracy are required, the more elaborate method outlined in ASTM specification C471-61 should be used.

5. Heavy Sands.—The majority of heavy sands were submitted as potential sources of titanium minerals.

It is doubtful if many of them received from prospectors are representative of significant deposits but as the process of mineral identification usually calls for gravity and magnetic separation most results can be reported on a semi-quantitative basis without additional time.

Samples were received, as in the past, from a number of coastal areas but in 1966 the proportion from inland centres was unusually high. These latter localities included Greenbushes, Quairading, Nannup, Mundijong, Jimperding, Cullculli, Corrigin, Nanson, Wiluna and Mabel Downs.

A heavy sand of particular interest originated from the Whim Creek area. The sample as submitted contained 43 per cent ilmenite and 26 per cent chromite, the remainder being quartz. The chromite was of high grade, assaying 61.8 per cent Cr_2O_3 with a chromium-iron ratio of 2.9 to 1. It occurred as well crystallised octahedra.

6. Iron.—Examinations were carried out for the Geological Survey and, to a lesser extent, for private companies on a large number of samples taken in connection with large scale iron ore developments.

Some unusual iron silicate minerals were encountered in bore cores from the Mt. Gibson deposit on which it is hoped to carry out detailed mineralogical and chemical work when an opportunity arises.

Potash was determined on six samples as an aid to assessing their potential as ferromanganese ore. The potash content of ore for this purpose, which is limited by specification, would be derived mainly from any cryptomelane present.

Two samples of ore, to be used as standards by a large iron ore company, were analysed for iron, silica, alumina, manganese, phosphorus, sulphur, titanium, vanadium, copper, zinc, lead, bismuth, nickel, chromium and tin.

7. Lead.—Lead assays were carried out on samples from the Northampton field for the State Batteries Branch and private operating concerns. One aspect of this work was the distribution of lead among the various sizing fractions of table tailings, giving data of value in assessing optimum crushing conditions.

Lead bearing minerals from the Kimberley area included galena associated with baryte, fluorite and quartz from Argyle Downs and galena, cerussite and anglesite associated with fluorite from Margaret River Station. A specimen from Liveringa Station was composed of galena, cerussite, pyrite and marcasite, while one from an island in King Sound was mainly galena with some pyromorphite and about 1 oz of silver per ton.

From the North West Division, anglesite from Range Station carried 7½ oz of silver per ton and a sulphide sample from the same Station assayed 59.6 per cent lead with over 10 oz silver per ton.

Specimens from Jigalong represented high grade sulphide ore with some pyromorphite; anglesite samples from Howatharra carried traces of copper and zinc minerals as well as small amounts of a mineral similar to hinsdalite, a rare lead aluminium sulpho-phosphate.

The mineral belongs to the beudantite-plumbogummite group and though its X-ray diffraction pattern is similar to hinsdalite, preliminary chemical work suggests the replacement of much of the aluminium by iron resulting in perhaps a closer affinity to corkite, the basic lead iron sulphophosphate. It is hoped to carry out further detailed work on this mineral when more sample is available.

A sample from an unspecified locality was a complex association of galena with quartz, sphalerite, chalcopyrite and their alteration products. The following species were identified among the alteration products; yellow bindheimite (lead antimonate), anglesite, green antlerite (basic copper sulphate) and blue linarite (basic copper lead sulphate). The sample assayed 74.6 per cent lead and carried about 5 dwt gold and 150 oz silver per ton.

8. Limestone.—Limestones were submitted to determine their suitability for a variety of purposes including agricultural dressing, raw material for cement manufacture, foundation stone and flux for blast furnaces.

9. Lithium.—A considerable amount of analytical work was carried out on products from the Londonderry feldspar quarries. This was mainly in connection with export shipments of petalite by the Company operating the quarries but work of a more academic nature was also carried out to assist a research programme being undertaken by a W.A. University honours student.

Among other samples from the quarries being tested as potential sources of lithium were two consisting of quartz and eucryptite. Though eucryptite contains over twice the percentage of Li_2O that petalite does the two samples examined carried too much gangue for the overall sample to reach shipment grade. Cookeite was also identified in samples from this area.

Another Londonderry rock popularly known as hornstone, was shown to consist largely of altered petalite having widely varying Li_2O contents from sample to sample.

Most analytical work involved only the determination of lithium and iron contents but a number of samples were subjected to detailed mineralogical and X-ray examination, as well as analyses for calcium, lithium, sodium and potassium in connection with the research programme mentioned above.

Lepidolite samples were received from Payne's Find, Ubini, and Wodgina. Only one contained the minimum commercial lithia content, namely 3.5 per cent. One sample from Wodgina was more correctly described as a lithium-bearing muscovite while a second sample from the same area, containing 2.11 per cent lithia, was difficult to classify as between lepidolite and zinnwaldite.

Spodumene was identified in specimens from Ravensthorpe but no other lithium-bearing minerals such as amblygonite, montebrasite or lithiophilite were received during the year.

10. Manganese.—The usual range of manganese minerals was examined during the year. These included psilomelane from Glen Florrie, crytomelane from Horseshoe, Mt. Gibson, Bullfinch, and Johnson Lakes and pyrolusite from Ilgararie and near Mt. Stuart.

The cobalt-bearing manganese minerals from St. Ives have been mentioned elsewhere under cobalt.

The most striking specimen received was from 30 miles South of Mt. Sydney and consisted of exceptionally well formed radiating crystals of pyrolusite.

11. Phosphate.—Following publicity stressing the need to discover phosphates in Australia a considerable number of samples were sent in by prospectors and the general public for phosphate determination. None contained significant concentrations of phosphorus, the large majority in fact containing less than 0.1 per cent of P_2O_5.

Sixteen samples of noritic and related rock samples from the Jimberlana Dyke, Norseman, were analysed for phosphorus to assist a W.A. University honours student in his petrological study of this dyke. Phosphorus was, as expected, in the parts per million range.

A green mineral from Milgun Station proved to be a particularly good specimen of fine-grained variscite (hydrated aluminium phosphate).

Sludge pumping of Mooka Bore in the Kennedy Range damsite brought to the surface a brown clayey material containing a proportion of a blue mineral. The blue mineral was identified as vivianite, a hydrated ferrous phosphate having a theoretical P_2O_5 content of 28.3 per cent. Vivianite alters rapidly on exposure, from a colourless mineral to a deep blue pleochroic mineral and finally to an isotropic semi-amorphous brown material. All stages were observed in the sludge sample examined. The sample contained about 10 per cent P_2O_5, suggesting a vivianite (and alteration products) content of about one third.

12. Silver.—Silver assays were requested mainly on copper ores and lead concentrates.

A sample from an undisclosed locality consisted mainly of galena (it assayed 74.6 per cent lead) but contained also minor amounts of sphalerite, chalcopyrite and their alteration products bindheimite, anglesite, antlerite and linarite. Though the gold content was less than 5 dwt per ton, it assayed 150 oz of silver per ton.

Most silver assays were carried out for private individuals or mining companies but probably the most interesting silver occurrance was from Marvel Loch, in tailings from a State Battery crushing. The tailings assayed 3.6 dwt of gold per ton but contained over 8 oz of silver per ton. This high silver assay was traced to the presence of the rare silver iodide mineral, miersite. X-ray diffraction patterns of this mineral were identical with those of miersite from Broken Hill and of synthetic silver iodide, but contained a line at 3.94 Angstroms which is not listed in the ASTM card for gamma silver iodide. It is hoped to obtain further supplies of this material so that chemical analysis and additional microscope work can be undertaken.

13. Tantalum and niobium.—Work on tantalum and niobium bearing minerals was about equally divided between grading commercial parcels by the specific gravity of the tantalite-columbite mineral fraction, chemical assaying of more complex parcels and the identification of such minerals in prospector samples.

Material that could be graded by specific gravity ranged from almost pure columbite from the Windsor Station (sp.gr. 5.2, Ta_2O_5 1 per cent, Nb_2O_5 79 per cent) to a high grade tantalite from Mt. Edon (sp.gr. 7.1, Ta_2O_5 67 per cent. Nb_2O_5 17 per cent).

Chemical analyses were made on a number of sales parcels in which for some reason or other pure tantalite-columbite fractions could not be separated or which contained tantalum minerals other than tantalite. One such parcel, originating from the Pilbara area, consisted mainly of an iron-stained mixture of wodginite, tapiolite, tantalite, microlite and simpsonite with about 1.8 per cent of cassiterite. Wodginite, the tin-bearing iron manganese niobo-tantalate, was the predominant mineral and accounted largely for the 6.73 per cent tin content of a parcel carrying only 1.8 per cent of cassiterite.

Other tantalum bearing minerals received included a metamict columbite from Marble Bar and tapiolite from Mt. Edon. The latter occurred as fragments in a matrix of fine calcite and clay, carrying also traces of microlite. Some unusual forms of columbite from the Mt. Francisco area were in exceptionally well developed rosettes formed from radially grouped aggregates of parallel twin crystals.

Details were obtained for a Swiss firm seeking sources of supply of tantalum alternative to their existing ones in South Africa. Particulars were tabulated covering producers, localities, tonnages and grades of columbite-tantalite mined in W.A. during the previous five years.

14. Tin.—The big majority of tin assays was on sales parcels of cassiterite concentrates. With few exceptions these were of acceptable grade, one exception being a mixture of 40 per cent cassiterite, 40 per cent leucoxene and the remainder mainly garnet.

Most sales parcels were assayed for tin only but on five occasions arsenic, antimony, bismuth, copper and lead were also required. These were present in amounts usually considerably less than 0.01 per cent.

A parcel of concentrates from Greenbushes assayed 0.55 per cent antimony trioxide, derived from the 1 to 2 per cent of stibiotantalite present.

A number of geochemical samples were submitted. These were handled by careful panning followed by determination of the tin in the resulting concentrates. Though the possibility exists of some loss of tin in the fines by this method, it allows volumetric methods of determination to be used and gives results which can be realistically compared with those likely to be obtained in practice. Atomic absorption would be the ideal technique for handling such samples but to date problems associated with the determination of tin by this method have not been satisfactorily solved.

Work was carried out for the State Batteries Branch on the distribution of tin throughout various size fractions of tailings from the treatment plant at Marble Bar. Similar work was done for private interests on material from a stockpile on the Moolyella fields.

An unusual specimen of translucent white cassiterite was received from the Mt. Francisco area. Though the existence of cassiterite in this form has long been accepted, these specimens represented the first submitted to these Laboratories and the first recorded occurrence in Western Australia.

15. Titanium.—Much of the work on titanum-bearing minerals has been carried out on behalf of established firms recovering heavy minerals from coastal deposits. The work has covered both mineral determinations (quantitative and qualitative) and chemical analyses, the latter largely to determine impurities present, though complete analyses of current production samples have also been carried out.

Examination of plant fractions to determine the distribution of the various minerals has involved the identification and semi-quantitative determinations of ilmenite, leucoxene, zircon, monazite, rutile, anatase, quartz and heavy silicates such as tourmaline, staurolite and garnet. Chemical determinations were made for titanium, total rare earths, thorium, phosphorus, zirconium, vanadium and chromium.

An examination of what was probably fairly typical of the hard "coffee rock" encountered in mining operations for heavy sands in the Capel-Busselton area showed the rock to consist essentially of a ferruginous sandstone containing ilmenite grains which are strongly cemented mainly by iron oxides. The approximate percentage mineral composition was found to be ilmenite 35 to 40, magnetite 5 to 10, iron oxides other than magnetite 20, zircon 5 to 10, leucoxene 1 to 5 and about 20 of minerals of specific gravity less than 2.85. Chemical analysis showed total iron 25 per cent, total titanium 17 per cent.

Mineral Identifications.

The acquisition of a GKN micro-hardness tester has added another diagnostic tool to those already available.

The unit is attached to a standard polarising ore microscope on which a departmentally made micro-reflectometer has already been mounted. Identification of small amounts of opaque minerals can now be made with greater precision based on reflectivity—micro-hardness ratios supplemented by other optical properties.

However, previous published data on reflectivity have been based for the most part on white light values and such results are considerably biased by the spectral response of the particular photocell used. Work has been commenced in this Division on the measurement of micro-hardness and reflectivity on the same polished areas of ore mineral, using minerals from both the Divisional and Simpson mineral collections.

1. Miscellaneous.—Arsenopyrite was identified in a number of specimens, including samples from Boulder, Marvel Loch and Field's Find. The Boulder specimen was associated with pyrite, pyrrhotite and chalcopyrite but the suspected telluride was not detected. The specimen from Field's Find carried nearly 10 dwt of gold per ton and was associated with minor amounts of galena and pyrite as well as quartz, dolomite and chlorite as gangue minerals.

Other arsenic bearing minerals submitted included the iron arsenide lollingite, arsenobismite, olivenite and cobaltite.

Lollingite from Jerramunup was a minor constituent in a quartz-feldspar rock, while a sample from near Lake Grace was obtained by panning sand from a quartz-goethite rock.

Among a number of samples taken from the complex formations in the vicinity of Koonong Pool in the Ashburton was one composed mainly of quartz, goethite and sericite but carrying lesser amounts of oxidised lead and copper minerals as well as the hydrous bismuth arsenate, arsenobismite. The hydrous copper arsenate, olivenite, was also identified in rocks from this area.

Cobaltite was present in dump samples from the Whim Creek area. These samples also contained free gold, malachite, axurite, pyrite and a cobaltiferous siderite.

Mimetite, the lead chlor-arsenate, was present in small amounts in a predominantly quartz rock from 14 miles south of Coolgardie.

Antimony bearing minerals examined included stibiotantalite, tetrahedrite and bindheimite.

The stibiotantalite was present to the extent of 1 to 2 per cent in a tin-tantalite concentrate from Greenbushes; the tetrahedrite was the only sulphide mineral in a sericite quartz amphibole rock from Ashburton Downs carrying also 3.2 dwt of gold per ton.

A banded rock from Range Station consisted of quartz, goethite and galena with yellow patches of the lead antimonate, bindheimite.

A polished mount was submitted for identification of a pale pink mineral present as veinlets throughout the specimen. It was possible to identify the mineral as a member of the linnaeite series but insufficient material was available to carry out the chemistry necessary to determine the actual species. The linnaeite group includes the minerals linnaeite Co_3S_4, siegenite $(CoNi)_3S_4$, carrollite Co_2CuS_4, violarite Ni_2FeS_4 and polydymite Ni_3S_4 all of which have similar optical properties and X-ray diffraction patterns.

A very wide range of silicate minerals was received, a random selection includes miloschite from Wubin and North Ironcap; nontronite from Meekatharra, Kirkimbie Station, Southern Cross and Geraldine, pyrophyllite from Coolgardie, kyanite from Yanmah and Limestone Springs (W. Kimberley), a fluorescent andalusite from the abandoned Mountain Queen gold lease, pumpellyite forming part of a calcite-clay matrix containing tapiolite originating from Mt. Edon and holmquistite from the Mt. Marion pegmatite.

A pink specimen from Young River, adjacent to the well known vermiculite deposit was submitted as a suspected rhodocrosite. The pink mineral proved to be zoicite, associated with albite and green tremolite.

The manganese-bearing ziosite (thulite) was identified from Jimperding while a rather uncommon chabazite rosette was sent in from Boyup Brook. A sample from Roebourne supposed to be rhodonite, was classified as a member of the epidote group. X-ray and optical evidence did not supply sufficient data for its more definite identification, provisionally suggested as clinozoisite.

A specimen of dolomitic marble from Wyloo Station polished to an attractive patterned finish.

The sustained popularity of cutting and polishing stones as a hobby resulted in many specimens being submitted for classification and comment on their potential as lapidary material. Amongst these were a green microcline from Belele Station, chrysoprase from Kookynie, prase from Roebourne, oncosine from Manganoon, agate from Pinder Bay, chalcedony from Mt. Herbert, chrysoberyl from Poona and prehnite from Mt. Ida.

Two pseudomorph specimens were of collector interest. One, from an island in King Sound, was composed of well formed "devil's dice" in cubes up to 3 inch sides and showing residual pyrite at the centre. The other was a cluster of pseudomorph crystals showing equal development of cube and octahedron, possibly originating from pyrite.

The Department of Fisheries and Fauna submitted a sample of material from Nanarup beach which local residents claim had only been evident during the past two or three years. The sample proved to be pumice, believed to have originated from volcanic eruptions in the South Sandwich Islands, between South America and Antarctica, in 1962.

2. Artificial Minerals.—The usual range of inorganic materials, not of natural origin but believed by the senders to be mineral species, was received during the year.

These included bronze and other copper alloys, finely divided metallic lead, lead spheres almost certainly spent shotgun pellets, solder, ferrosilicon and ferrochrome, and several metallurgical products, mainly slags.

A specimen of "sand cake" was received from Eaton, through a district office of the Department of Agriculture. As received, the sample was a resilient mass with a thin surface layer of darker friable material. About 75 per cent by weight of the sample consisted of clear rounded quartz grains loosely held together in a mat of clear transparent fibres. The fibres could not be recognised at these Laboratories but the sample was subsequently identified by the Government Botanist as a false sclerotium made up of threads of fungal material holding sand grains into a compact mass.

3. New Localities.—Minerals for which new Western Australian localities were recorded in 1966 are listed below.

Mineral.	New Locality.
	(a) Kimberley Division.
Galena	Sunday Island.
Pyromorphite	Sunday Island.
Pyrite	Mary Island.
Galena	Liveringa Station.
Cerussite	Liveringa Station.
Noonkanbahite	Wolgidee Hills.
Chamosite	Narlala.
	(b) North West Division.
Baryte	18m. S.S.W. of Mia Mia Homestead.
Baryte	Hill Springs Station.
Baryte	Murramunda Homestead.
Cassiterite	Corunna Downs Station.
Ilmenite	4m. W. of Cookes Creek wolfram field.
Tetrahedrite	7m. W. of Ashburton Downs Homestead.
Olivenite	7m. W. of Ashburton Downs Homestead.
Bindheimite	8m. W. of Range Station.
Bindheimite	Bamboo Creek.
Corundum	Yandeearra Reserve.
Vivianite	Kennedy Range.
Galena	5m. N. of Range Homestead.
Galena	Murramunda Homestead.
Dolomite	Mt. Tom Price.
Cerussite	Murramunda Homestead.
Anglesite	Murramunda Homestead.
	(c) Murchison Division.
Columbite	30m. N.W. of Byro Homestead.
Corundum	4m. E. of Lakeside Homestead.
Cassiterite	Sawback Range.
Prehnite	10m. N.W. of Beebyn Homestead.
Beryl	Wadgingarra.
Fluorite	Mt. Farmer.
Fluorite	Chesterfield.
Bismuth	15m. E. of Peak Hill.
Bitmutite	15m. E. of Peak Hill.
Rutile	15m. E. of Peak Hill.
	(d) South West Division.
Mineral.	
Olivine	Scott River.
Cryptomelane	8m. S. of Maggie Haye Hill.
Beryl	Mt. Day.
Tapiolite	Mt. Edon.
Pumpellyite	Mt. Edon.
Lollingite	Lake Grace.
Corundum	4m. S. of Payne's Find.
Chabazite	Boyup Brook.
Taranakite	Super Cave, Cervantes.
Ardealite	Jurien Bay.
Brushite	Jurien Bay.
Dahllite	Jurien Bay.
	(e) Central Division.
Columbite	4m. N.N.W. of Marvel Loch.
Columbite	Mt. Marion.
Anthophyllite	20m. S. of Coolgardie.
Magnesite	Mulgabbie.
Ilmenite	Mt. Palmer.
Mimetite-pyromorphite	14m. S. of Coolgardie.
Cryptomelane	3m. N. of St. Ives.
Alunite	Yerilla Station.
Lithiophorite	3m. N. of St. Ives.
Holmquistite	Mt. Marion.
Laumontite	Londonderry.
	(f) Eucla Division.
Petalite	6m. S. of Norseman.
Cassiterite	6m. S. of Norseman.

Miscellaneous Analyses.

1. Burnt Lime.—Only three battery lime samples were submitted by the State Batteries Branch, the lowest number for many years. All were of good quality.

Most analyses of lime were carried out in connection with investigation by the Engineering Chemistry Division on the calcination of beach sands. Various products from this work were analysed for total and free lime, magnesia, silica and potassium. A sintered deposit forming in the calciner shaft was shown to be essentially the alpha form of calcium silicate.

2. Corrosion Products.—Corrosion products were examined for a number of organisations. Sludge from a truck sump was shown to consist of ferrous sulphate, barium sulphate and quartz. Barium salts are used as additives to some oils and the presence of this element as a sulphate in addition to large amount of iron sulphate suggested the existence of acid conditions. Deposits from the exhaust system of an engine were found to consist of sulphates of calcium, barium, sodium, and vanadium

A product from inside a power-house transformer was mainly iron oxide and metallic iron but the presence of formates was also established. These latter could possibly have originated from a urea formaldehyde resin such as bakelite.

Boiler deposits, examined in conjuction with Fuel Technology Division, proved to be highly acid and to consist mainly of iron sulphates.

3. Metals and Alloys.—Work on metals and alloys was carried out for Public Works Department, Main Roads Department and Metropolitan Water Supply Department as well as for the University of Western Australia and members of the general public.

In addition to analytical work, examinations and measurements were made by optical means of a number of alloys and metals. These included the measurement by optical micrometer of the thickness of anodic films on aluminium, examinations to determine why sewer rods failed in service and why antimonial lead battery terminals were unsatisfactory. An attempt to determine the microstructure of a steel cable failed as the structure proved too fine for resolution by an ordinary microscope at 1,000 magnifications but electron micrographs carried out elsewhere at magnifications of 20,000 provided the necessary information.

Examination of the rods used for clearing sewerage pipes showed that their failure in service was due to the enlargement of minute cracks originally formed in the processing of the rods. This enlargement was due mainly to stress during use but a contributing factor would be the accelerated fatigue failure resulting from their use in a corrosive liquid environment.

Failure of the battery terminals was shown to be due to the brittleness of the antimonial lead alloy resulting from segregation of the antimony. This segregation could probably be overcome by pouring the metal at higher temperatures and controlling the cooling rate.

Chemical analyses of alloys were carried out for the evaluation of scrap metal and for checking alloys against specifications. For these purposes determinations were made of copper, zinc, tin, antimony, cadmium, iron, aluminium, magnesium, silicon and indium.

Determinations were made for the University of the antimony-indium ratio in metallic films of an alloy of these elements. Material available was in microgram quantities. The indium was determined colorimetrically after extraction with 8 hydroxy-quinoline, the antimony by atomic absorption.

4. Minerals.—A rather unusual vein material from Yerilla Station proved to be a member of the alunite-natroalunite series. Partial analyses gave the following figures:—

	Per cent.
K_2O	5.85
Na_2O	5.19
SO_3	36.2
Al_2O_3	26.2
Fe_2O_3	0.77

suggesting a member of the series about half way between the potassium and sodium extremes.

Another sample, from Young River, consisted of a mineral of the jarosite-natrojarosite series with a potash (K_2O) content of 4.6 per cent.

The only bismuth minerals received were from the Yinnietharra deposits and were all predominantly carbonates.

Two samples of detrital material carrying high bismuth concentrations were screened into five sizings. It was shown that they could be considerably up-graded by discarding the minus 40 mesh fraction without significant loss of bismuth in the fines.

Cobalt bearing minerals wele received from two widely separated areas and occurring in widely different forms. A rock from the Roebourne area consisted of hematite, goethite, quartz, feldspar, chlorite and pyrite and contained also about 1 per cent of the pink cobaltocalcite. Material from St. Ives was essentially a manganese mineral intergrown with quartz, fine-grained mica and goethite. The manganese mineral was identified as a cobalt and nickel bearing lithiophorite, assaying as high as 0.7 per cent nickel and 2.7 per cent cobalt.

Three samples were submitted by a public analyst for molybdenum determination. These samples were required for use as standards in developing atomic absorption techniques for use in the client's geochemical laboratory. Determinations were made by three different methods viz. colorimetric using thiocyanate and stannous chloride, gravimetric by precipitation with alpha-benzoinoxime and by atomic absorption using the air-acetylene flame. The samples ranged between 0.3 per cent and 0.5 per cent of molybdenum and agreement between the three methods was good.

A drill core from a considerable depth consisted mainly of water soluble material. Analysis showed these water soluble minerals to be predominantly halite but with lesser amounts of other alkali and alkaline-earth compounds also present.

A second core, from a greater depth, showed veins of pink and grey. Examination showed the presence in the pink material of trace amounts of hematite, calcite and goethite which were absent in the grey. The vastly predominating water soluble portions of each vein gave almost identical analyses.

Salt from Pink Lake, Esperance, was examined at the request of Public Works Department to determine its suitability for regeneration of cation exchange materials. The dry salt assayed over 99 per cent sodium chloride and except perhaps for an excessive free moisture content the material as submitted should prove satisfactory for the proposed purpose.

A suite of minerals from the Ashburton division was analysed for trace amounts of chromium, copper, lead, nickel, uranium, zinc and platinum. Platinum was not detected in amounts greater than 0.1 ppm, nor was uranium present in detectable amounts.

A number of samples of banded chert were examined for the Geological Survey in support of a general study of the Hamersley area blue asbestos being carried out by the Survey. On one suite of 10 samples total iron, ferrous iron and carbon dioxide were determined as well as acid soluble calcium, magnesium and iron.

Seven samples of aluminous laterites from the North Kimberleys, ranged in available alumina content from 8.8 per cent up to 39.8 per cent. The 39.8 per cent material carried only 0.87 per cent of reactive silica with 3.03 per cent titanium dioxide.

Four partial analyses of samples from the Brockman Iron Formation were made for Geological Survey to test a hypothesis that the iron required for crocidolite came out of carbonate in the immediately adjacent chert.

Fifteen samples from a suspected nickeliferous gossan from the Lake Rebecca area were analysed for nickel, chromium, copper, cobalt and platinum. Nickel varied from 0.02 to 0.78 per cent, chromium from 0.01 to 1.19, copper from 0.01 to 0.04, cobalt from a trace to 0.99 per cent. No platinum was detected.

A further batch of fifteen samples from the ultrabasic and basic differentiates of the Giles Complex, near the South Australian border, were tested for platinum but without positive results.

One hundred and fifty-nine samples of sandstone from the Precambrian Bangemall and Bresnahan Groups of the southern Pilbara were analysed for copper, lead, zinc, cobalt and titanium to assist the Geological Survey in their comparison between the African copperbelt rocks and these similarly aged rocks of Western Australia.

Examination was carried out of the heavy mineral content of five samples of sandstone formations in the Kennedy Range damsite area. The following minerals were determined by grain count on the heavy mineral fractions from these sandstones—goethite + leucoxene, zircon (colourless), zircon (pink), tourmaline, rutile, monazite and baryte. The baryte occurred as angular crystals and radiating aggregates showing no rounding or abrasion effects. It was concluded that the baryte was a secondary mineral formed after the compaction of the sandstone.

Twenty-five samples, mainly limestones, from the Eucla Basin were analysed at the request of the Geological Survey for sodium, potassium, aluminium, iron, calcium, magnesium, carbonate, sulphate, chloride and silica.

Some unusual cave minerals were identified, the most interesting being ardealite and taranakite from a cave near Jurien Bay and taranakite and brushite with dahllite-collophane from a cave on the Nambung River.

Work is still in hand on ardealite specimens from Jurien Bay. X-ray, D.T.A. and chemical work suggest the existence of three variants of this rare mineral. It is hoped to publish elsewhere detailed results at the conclusion of this investigation, which is a joint study shared with the Physicist and Pyrometry Officer.

Taranakite, a complex acid-soluble phosphate, was identified by X-ray diffraction. A slightly impure sample from the Nambung River cave gave the following chemical analysis calculated to an acid-insoluble free basis.

		Per Cent.
P_2O_5	....	40.90
Al_2O_3	....	18.34
Fe_2O_3	....	1.66
CaO	....	0.09
MgO	....	0.02
K_2O	....	3.72
Na_2O	....	0.17
H_2O (total)	....	34.90

5. Complete Analyses.—Most complete analyses were carried out at the request of the Geological Survey.

These included three lavas and a tuff from the Fortescue Group taken near the Yule River crossing of the Wittenoom-Port Hedland road, and a sandstone from 10 miles north-west of Ned's Creek Homestead. Other rocks assayed for the Survey were five bore cores from the pyritic Mt. McRae shale in the Wittenoom area.

At the request of a producing company a full analysis was made of a sample representative of their current ilmenite production.

Conferences and Talks.

Mr. M. B. Costello attended the Geological Society of Australian Specialists' Meeting in Adelaide on "Modern Methods of Rock Analysis for Constituent Elements."

Mr. M. Pryce attended a Computer Programming Course at the University of Western Australia.

Mr. R. W. Lindsey gave a talk on "Beach Mineral Sands" to the Lapidary Club of Western Australia and to the Gemmological Society.

PHYSICS AND PYROMETRY SECTION.

The work of this section is described under headings Pyrometry and Thermal and X-Ray Methods.

Pyrometry.

A total of six mercury in glass thermometers was calibrated by comparison with laboratory standards in the range 0° C. to 300° C., to accuracies ranging from ± 0.05° C. to ± 3° C. Two optical pyrometers were also checked by comparison with the laboratory standard.

Thermal and X-Ray Methods.

1. A group of twelve clay fractions separated from soil samples was examined both by the differential method and by X-ray powder diffraction. In all cases the predominating mineral present was kaolinite, with in some cases lesser quantities of montmorillonite, illite, quartz and felspar.

2. Phosphate Minerals.—After a first excursion to Smith's Cave in Jurien Bay in May (See Mineral Division Section of this report; also Mines Department Annual Report 1965 p. 196), the guano samples gathered were given preliminary X-ray examination, and these results were used to map the distribution of minerals in the cave. On the basis of this a second excursion was organised in September to complete the mapping, and gather fresh samples of particular interest. As a result of this visit, the distribution of minerals in the profiles of the main and one subsidiary guano pile will be studied. A technique for the polyester impregnation of boxed samples has been evolved in conjunction with the Industrial Chemistry Division and has been used successfully to solidify two boxes of the nodular horizon of the main guano profile. This will allow serial sectioning of this part of the deposit for optical examination, otherwise impossible due to the friability of the guano.

Further work on nodules containing ardealite (Annual Report 1965 p. 196) has elicited the fact that there are actually three minerals of similar composition and structure, only the first of which, tentatively named ardealite I, has the characteristic X-ray powder line which allowed its distinction from brushite and gypsum by Halla (Z. Krist. 80, 349, 1931). As observed so far, ardealite I may occur in nodules in this deposit together with ardealite II or ardealite III, but II and III have not so far been recognised together. Chemical analyses of II and III are given in Table 23 together with a partial analysis of I. The derived formulae are also shown. Note that the variation of the amount of water from the ideal 4 molecules may not be significant in this determination as the water was only determined by weight loss; the variation amounts to 0.5 per cent H_2O in the analytical results. The analysis of ardealite I, together with a brief description, has been submitted for publication elsewhere. The analyses of II and III indicate that the slight structural differences between them are due to variations in amount of HPO_3 and SO_3 and not to cation replacement.

From the foregoing it is clear that the results given in Mines Department Annual Report 1965 p. 196 for "? ardealite" were obtained on mixtures of different varieties of ardealite, and must therefore be reinterpreted.

3. X-Ray Fluorescence.—A study on the possible applications of X-ray fluorescence analysis to the work of the Chemical Laboratories was commenced by a visit to AMDEL and C.S.I.R.O. Soils Division in Adelaide. Following this some typical mineral and plant samples were processed at the Agriculture Institute of the University of Western Australia. Further references to the method's application to the analysis of silicates have recently come to hand, and a report on the subject will be completed early in 1967.

Table 24.

Ardealite.

	II	III	I
CaO	32.5	32.3	31.5
HPO_3	20.8	23.1	23.7
SO_3	25.5	23.0	21.9
H_2O	21.4	21.4	24.7*
Acid Insoluble	0.14	0.09	N.D.
Na	0.04	0.04	N.D.
K	0.01	0.01	N.D.
Mg	0.01	0.01	N.D.
Fe	0.02	0.01	N.D.
Al	<0.01	<0.01	N.D.
	100.4	100.0	101.8

* Includes adsorbed water.

Ardealite II: 2 CaO. 0.9 HPO_3. 1.1 SO_3. 4.1 H_2O.

Ardealite III: 2 CaO. HPO_3. SO_3. 4.1 H_2O.

Ardealite I: 2 CaO. 1.0_6 HPO_3. 0.9_7 SO_3. ? H_2O.

CONTENTS

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DIVISION VIII

Annual Report of the Chief Inspector of Explosives for the Year 1966

The Under Secretary for Mines

I am privileged to report to the Hon. Minister for Mines on the functioning of the Explosives Branch in 1966.

INSPECTION OF EXPLOSIVES AND BLASTING AGENTS

The Branch's fundamental function of ensuring that explosives complied with State requirements was pursued without relaxation. All incoming shipments and railages were attended, and despite the wider territory now to be covered, explosives storage and consuming points came under reasonable surveillance. In several instances where no one from Head Office was available, district inspectors of mines performed valued service on urgent overhauls and similar jobs.

Visual inspection, followed where applicable by the heat-test for stability, established all explosives on importation as satisfactory. Over-age and moisture absorption were the main reasons for condemning occasional small amounts in store or magazine.

At northerly ports, supervisory work directed both toward safety in handling and explosives quality was again beset with difficulties arising from uncertain shipping movements, inroads on time and the long journeys involved. As controller of these ports, the Harbour and Light Department showed commendable co-operation by instructing local officers-in-charge on their responsibilities. Recently, wharfingers were called to Fremantle for inspection of harbour works, familarisation with shipping matters and a general indoctrination course. At one session dealing specifically with explosives, Mr. G. A. Greaves and the writer both addressed the assembly. Later, the Department appointed a master mariner to act in liasion with the Explosives Branch by advising on and co-ordinating inspectional activity. Thus the future situation should be more ably met, but the need for expanding the branch's own inspectional facilities remains.

More than 4,400 tons of ammonium nitrate for blasting agent preparation was consigned to the State by Australian, American, Japanese and French manufacturers during 1966. Part wastage of one shipment resulted from wetting in transit, whilst another failed on analysis to fall within the upper limit for organic matter. With these exceptions, the prill was found to be of good quality and satisfactory oil absorptive capacity. However, packaging could be improved. Inspection of bagged A.N on landing, under conveyance or in storage all too frequently revealed spillage ranging from a few particles to amounts which had to be shovelled out of the way.

The final phase of inspection deserving of mention is that of ordnance movements to and from H.M.A. vessels at North Wharf or Woodman Point. Although naturally the inspector has no authority as to the composition and soundness of these explosives, vigilance has repeatedly paid off in detection and suppression of acts which could lead to fire or explosion.

AUTHORISED EXPLOSIVES.

The only addition to the official list was:—

Part B, Class D, Nitro-compound—

Division 2

Procure Booster (ZZ)

The sharp fall from 14 authorisations in 1965 does not connote flagging initiative in developing and introducing new explosives. Indeed, never before has such a range of blasting materials been available, but applications for authorisation naturally vary with the number of importers and the extent to which each strives for market exploitation. It so happened that no such increase occurred in 1966. There were, however, several instances of altered composition within authorised definition, and the practice of accepting sample or trial-size consignments of unauthorised foreign explosives was continued. Hence at any given time, the current list does not necessarily include every explosive potentially authorised or otherwise permitted for importation.

BLASTING AGENTS

Further incursion of ammonium nitrate-fuel oil mixtures into the former conventional explosives field was recorded. For clearing land of stumps and trees it has proven cheaper than by dynamiting or bulldozing. Field demonstrations were staged by commercial interests, and information prepared enabling almost anyone to perform this work effectively and safely. The Explosives Branch, inundated with inquiries and applications to manufacture blasting agent, has published in the journal of Agriculture under Mr. G. A. Greaves' authorship an article entitled "Ammonium Nitrate Blasting Agent (ANFO) for Land Clearing".

Deservedly so in the light of intense investigation and trial, metalliferous mining has benefited from the trend. Up to 97% replacement of conventional or dynamite-type explosives by ANFO was reported in some instances, and the earlier practice of boosting has declined. No such changeover occurred in colliery blasting because of special protection necessary with ANFO under the prevailing wet conditions.

Though more complicated than the simple mixtures, slurries fall within the blasting agent category in as much that an inexplosive premix is incorporated with a concentrated solution of oxidisers (nitrates or sodium and ammonium). In modern large scale practice the operation is carried out on specially equipped trucks from which the charge is pumped into the shotholes. This method of preparation and application is intended by an iron-ore mining company, whose estimated initial consumption of slurry is around 3,500 tons annually.

Surface activation of ANFO with the proprietary agent Quilox was further studied in laboratory and plant-scale trials. Results generally confirmed claims of greater sensitivity, which property, however, was also influenced by the make of ammonium nitrate prill. One recent importation of French origin showed to considerable advantage in this respect, and in fact most makes prepared and charged by present technique are detonable by a No. 8 cap, or with less certainty by a No. 6. Provided it lies within limits of safety in handling and use, sensitivity is a desirable characteristic. Difficulties abound in attempting to differentiate between a blasting agent, as ordinarily understood, and another substantially identical composition responsive to detonation of a lower order. The U.S. Bureau of Mines' criterion of a blasting agent is failure to detonate by a No. 8 cap under defined conditions, whereas the W.A. Explosives and Dangerous Goods Act (1961) and Regulations are not specific on the point. Fortunately so; for too rigid a conception of what constitutes blasting agent would outlaw its use unless manufactured under licensed factory conditions and marketed as an authorised explosive.

In view of the foregoing statement it may appear incongruous that Molanal, though lending itself to on-the-spot preparation from inexplosive components, was authorised as an explosive about a year ago. Certainly this composition necessitates the blending of at least four substances compared with two in the prototype ANFO. Such a consideration, along with the accurate and precise compounding for best results, inclined the proprietors of Molanal toward professional manufacture. Consequently W.A.'s Molanal requirements will continue to come from the Victorian explosives factory until manufactured locally. Planning for a small plant at Woodman's Point and possibly another in the north is now well advanced.

IMPORTATION OF EXPLOSIVES AND BLASTING AGENTS.

The established shipping practice as outlined in earlier reports underwent little change beyond increased use of north-westerly ports. Ammonium nitrate was also discharged at the Fremantle North Wharf, advantage being taken of the modern trend to seatainer packaging. Railage from Eastern Australia continued to supply goldfields' requirements and occasionally to supplement coastal stocks.

Greater shiploading of explosives and ammonium nitrate, either separately or in composite, was studied from the safety and economic angles. Though limited to some extent by the size and draft of vessels which may be accommodated, the present 400 ton maximum at Woodman Point Reserve Jetty has lagged behind demand. Such problems are discussed periodically by the Australian Port Authorities' Dangerous Goods Sub-Committee, whose findings and recommendations are duly submitted to the Permanent Committee for decision. A factor beclouding certain earlier issues was the loose use of terms such as "special" "isolated" and "nitrate" berths, which, under investigation, were found to lack definition as to remoteness from protected works. The W.A. attitude inclines to assessment of isolation on the Official Table basis. In effect, explosives afloat should not warrant different treatment from the same weight magazined on land. Another consideration is that whereas immobile storage may be continuous or slowly reducible, transfer of explosives from a berthed ship's holds and their dispersal in various magazines proceeds at a rate up to 200 tons per eight-hour day.

Distance-wise, Woodman Point Reserve is so remote from shipping lanes, the inner harbour and built-up areas that heavier seaborne explosives traffic would be justified. These views were sympathetically received by the Fremantle Port Authority with whose collaboration a strong case has been prepared for presentation at the next Sub-Committee meeting convened by the Maritime Services Board in Sydney for February, 1967.

STATE EXPLOSIVES RESERVES.

Woodman Point.

Progress is reported in upgrading the 1,600 ton storage, at present spread so widely over this well-situated block. A check survey of distances having confirmed that storage points were separated in excess of the minima prescribed by the Inter-Departmental Explosives and Transport Committee of the U.K. the general principle of heavier loadings in fewer magazines, enlarged if necessary, was adopted. An exception had to be made in the instance of seven buildings in No. 1 line, which through proximity to continually increasing road and rail traffic just east of the boundary could not justifiably be relicensed for their former 30 ton capacity. However, no loss need be incurred if these magazines are stocked with non-explosives such as ammonium nitrate, or used for detonators or other accessories of low explosive to bulk weight ratio.

Before formulating the above plan, an analysis of past and present quantities in storage, with due allowance for emergency loading and estimated future requirements, was undertaken and acted upon in the reallocation of sites and amounts. This re-arrangement will be brought about in stages rather than immediately, and neither of the established importers need suffer reduction in reasonable requirements. The consolidation of stocks may effect small savings in time and haulage costs. From the departmental viewpoint, availability of land rendered possible by resumption of former leasehold sites is an important forward move both toward augmented public storage facilities and the ability to accommodate newcomers to the explosives trade.

Various factors such as rationalized storage, provision for ammonium nitrate and relief accruing both from direct railage to the Eastern Goldfields and diversion of shipments to N.W. ports have so far enabled the privately owned magazines on the Reserve to cope with normal throughput, whilst still leaving several leasehold sites for future buildings. But neither can the importers' nor the departmental magazines accommodate surge loadings, as when 500 tons of nitrocarbonitrate explosive arrived a year ago. Such consideration, coupled with rapidly increasing explosives consumption by the State's great industrial undertakings, directs attention to the urgency for planning supplementary or even alternative sites to the present area.

Kalgoorlie.

Four magazines floored with an impervious overlay suffice for the district's ammonium nitrate requirements. No over-taxing of detonator and conventional explosives storage has occurred, and space is available on the block for additional magazines if ever required.

Port Hedland.

The outmoded small reserve was relinquished, and after failure of earlier negotiations, an elongated 100 acre tract bounded by Pippingarra Pastoral Station and Wittenoom Road became gazetted. By late November, several hundred tons were stored there, with expected increase to about 800 tons as more magazines are built.

Geraldton.

The original block, apparently in disuse for many years preceding its resumption for a flora and fauna reserve, was replaced by one of 21 acres on rising ground from the Chapman River. After the local authority constructed a half-mile access road, development was pushed ahead because of applications for leasehold magazine sites. Buildings for at least 60 tons storage will be in use by the second quarter of 1967, and applications for extra sites are pending.

Other Localities.

At most ports from Esperance to Wyndham interest has been evinced in explosives landing, handling and storage facilities. Recent inspection at Carnarvon revealed distinct possibilities. Broome has already received several seaborne explosives consignments and advance information indicates that Onslow will come into the picture with geoseismic explosives importations for months hence.

Mechanisation at Explosives Reserves.

Fork-lift handling of palletized bagged or drummed ammonium nitrate was introduced by one importer. The other, not ordinarily concerned with pallets, acquired a belt conveyor to facilitate movement of the bags into and out of storage. There being no mains current available at such points, this machine is powered by A.C. from a petrol engine generator set, located outside the blast mound when in use. Cables connecting with the conveyor's flameproof motor have presented no hazard. Hydraulic operation, originally suggested, met with disfavour because of danger consequent upon possible leakage from oil pressure lines.

Late in the year, the Branch took delivery of a small tractor and various attachments. Apart from obvious use in desanding railway tracks, occasional or after-hours manoeuvring of rolling stock, transporting men and equipment to derailments, etc, it shows promise in scrub-cutting to maintain the miles of firebreak in the area. Formerly occupying up to three months by tedious manual methods, this work may be completed in under a fortnight with the tractor and cutter combination.

DESTRUCTION OF EXPLOSIVES AND DANGEROUS GOODS.

Several kilograms of illegally imported rifle powder were destroyed by Customs request. Periodic burning of condemned or unwanted explosives took place without incident.

Small amounts of dangerous goods including a sample of tetranitromethane usually kept in refrigeration, and said to be detonable by heat or shock, presented no difficulties. Against this, a problem arose in the instance of 26 drums containing some 500 gallons of "Aquilin", an acrylic aldehyde herbicide, highly toxic, flammable and prone to develop even more hazardous properties on prolonged storage. As a proposal to dump at sea was disallowed by the Port Authority, the Branch officers in collaboration with an Irrigation and Drainage Department engineer propounded a plan whereby the drums were punctured one at a time by rifle fire to permit the contents to run into burning waste. Respirator equipped operatives, working at an isolated rubbish dump, encountered no trouble in carrying out the destruction.

ACCIDENTS—EXPLOSIVES UNDER CONVEYANCE

On 6th June the freighter "Gertrude Therese" laden with 223 tons of ammonium nitrate and 91 tons of canned N.C.N. explosive grounded on a reef off Adele Island, north of Derby. Whilst awaiting a high tide for attempted refloating, salvage operators decided that cargo must be removed to lighten the vessel. Valuable North-West Cape radio equipment was saved and the N.C.N. barged undamaged to Cockatoo Island, but for lack of suitable craft all the nitrate had to be jettisoned.

Fire and explosion destroyed a truck and its 600 case load of Geophex explosive near Mt. Magnet on September 8th. Fuel which ignited on escape from a fractured line was the assigned cause of the fire, and when attempts at extinguishing proved abortive the driver wisely took shelter. Though stated to be only about 200 yards from the explosion which duly occurred, he sustained but slight injury. Obviously most of the explosive had burnt before the remainder detonated. Nevertheless, the blast cratered the road, broke windows and plaster in the town and heavily damaged a station sedan belonging to a constable investigating the fire.

Liquid from severed hydraulic lines contaminated some fuse and explosives among a 4 ton load on a truck involved in collision near Port Hedland on October 8th. Neither fire nor explosion occurred. Two schoolboys, who should never have been passengers on an explosives-carrying vehicle, died from injuries received in the crash.

FIRES OR EXPLOSIONS INVOLVING DANGEROUS GOODS

Pickands Mather and Co's geochemical laboratory at Victoria Park was wrecked and valuable equipment ruined by fire and two explosions on June 9th. What started the ignition could not be determined. A significant finding was the substandard plumbing used to pipe L.P. gas into the laboratory from an outside container, of which the release valve had not been closed. Two other cylinders, one containing acetylene and the other nitrous oxide, had blown their safety plugs, allowing gas to escape. As the fire progressed, vapor from flammable solvents could have caused the first explosion whilst the second more devastating blast was apparently associated with 18 gallons of perchloric acid stored under a fume hood. A cratered concrete floor below lent force to the conclusion that the perchloric acid, a strong oxidising agent unstable when heated, had detonated violently on contacting organic matter.

A man was injured and his wife killed at a Gosnells fruit-ripening shed on May 3. The woman was preparing acetylene gas from calcium carbide and water in apparatus near a radiator, which presumably fired the air-gas mixture, with disastrous results.

Other accidents were investigated or brought under notice for comment, especially when coronial inquiry was ordered. Certain features shared by most cases served to drive home the lessons that good housekeeping, deference to regulations and commonsense measures with electricity, chemicals, flammable and dangerous goods generally could prevent or at least lessen the severity of many disasters.

DANGEROUS GOODS REGULATIONS

Although still not in final form, a recently amended draft marked considerable progress over the one which appeared toward the close of 1965. The work was constantly discussed with the W.A. Fire Brigade Board and every effort made to conform with the Chief Officer's requirements as to fire protection, tank vehicles and flammable liquid storage. Similarly the W.A. Automobile Chamber of Commerce offered advice on regulated storage at filling stations.

During April, Mr. G. A. Greaves conferred with the Australian Paint Manufacturers' Federation in Sydney and later met a sub-committee of the Petroleum Marketing Engineers' Advisory Committee at Melbourne. These contacts brought forth a better understanding by all parties and an adjustment to several features before the revised code was submitted to the Parliamentary Draftsman. Save for some dissentient opinions regarding fire protection measures at tank depots, the new draft was well received. On present indications, only a few alterations need be made prior to promulgation.

Ever since dangerous goods and flammable liquids controls were mooted about seven years ago, a commendable industrial and general public urge to comply with requirements has been apparent. The Branch's difficulties in explaining and interpreting intended but still ungazetted regulations may well be appreciated. However, the formative stages are now virtually passed, and with emphasis on the necessity for extra staff and accommodation in advance of the regulations being proclaimed, their effective implementation should follow.

PYROTECHNICS.

The year's most momentous development occurred in November by the passage of legislation to ban shop-goods class fireworks. Until its proclamation in original or amended form, no comment is made beyond stating that public misunderstanding regarding marine signalling devices, fuse lighters and various small novelty lines has been clarified. The Branch received instruction to carry on its normal functioning prescribed by the Explosives and Dangerous Goods Act (1961) and Regulations until advised otherwise.

The 1966 season was almost uneventful, with a continued trend to safer and simpler fireworks. Noise reduction is exploding types, already considered departmentally as desirable, met with general approval by the trade. Samples of all importations accorded with requirements except for a few sharp-pointed rockets and a "jet-plane" of unpredictable and erratic flight. An earlier reported occurrence of arsenic in streamer bombs focused attention on locally available samples, which, however, were found on chemical analysis to be innocuous.

Despite stricter control over time, place and noise volume, firework displays have retained popularity. Few complaints and no reports of injury to spectators were registered.

Fuse lighters made by a locally licensed display firework technician proved on examination to be satisfactory though not economically marketable. Ships' distress signalling devices of Eastern States manufacture, submitted by the Harbour and Light Department, lacked the positive performance expected of such articles. Their difficult and uncertain ignitibility, proneness to deterioration by wetting and ejection of incandescent particles failing to extinguish at ground level could not be tolerated.

STAFF

Appreciation is recorded of Mr. L. M. Calneggia's clerical services from 1954 until transfer under promotion to another Department last July. Though part time relief was provided the year closed without permanent appointment, thus aggravating difficulties in coping even with routine business. For reasons previously stated, several inspectors of Dangerous Goods should be engaged for training in implementation of the Regulations when operative. On the professional staff side, another officer of sound chemical background is deemed necessary if the Branch is to maintain its functions and keep abreast with rapidly developing explosives technology. Apart from its present value, such an appointment could facilitate adjustments after the writers' retirement in February, 1968.

Acknowledgements

Whether of kindred or diverse interests, Government departments and instrumentalities have rendered commendable service to the Branch. Relationships with established explosives importers and others seeking to exploit the market continued at high level. To my staff at head office and the explosives reserve, gratitude is expressed for faithful and diligent dedication to duty.

F. F. ALLSOP,
Chief Inspector of Explosives.

DIVISION IX

Report of Superintendent, Mine Workers' Relief Act, 1966 and Chairman, Miners' Phthisis Board

Under Secretary for Mines:

I submit for the information of the Honourable Minister for Mines my report on this Branch of the Mines Department for the year, 1966.

General.

The State Public Health Department, under arrangements made with this Department, continued the periodical examination of mine workers, the work being carried out through the year at the State X-Ray Laboratory, Kalgoorlie, and a mobile x-ray unit visited the Coolgardie, Yilgarn, Dundas, Phillips River, North Coolgardie, East Murchison, Murchison, Yalgoo, Pilbara and West Pilbara Goldfields, the Northampton Mineral Field and the South West Mineral Field.

Mine Workers' Relief Act.

Total Examination.—The examinations under the Mine Workers' Relief Act during the year totalled 3,941 as compared with 4,314 the previous year, a decrease of 373. The results of examinations are as follows:

Normal	3,411
Silicosis early previously normal	26
Silicosis early previously silicosis early	469
Silicosis advanced previously normal	Nil
Silicosis advanced previously silicosis early	14
Silicosis advanced previously silicosis advanced	Nil
Silico-tuberculosis previously normal	Nil
Silico-tuberculosis previously silicosis early	4
Silico-tuberculosis previously silicosis advanced	Nil
Tuberculosis previously normal	1
Asbestosis early previously normal	1
Asbestosis early previously asbestosis early	6
Asbestosis advanced previously normal	Nil
Silico-asbestosis early previously normal	3
Silico-asbestosis early previously asbestosis early	Nil
Silico-asbestosis early previously silicosis early	Nil
Silico-asbestosis early previously silico-asbestosis early	6
Silico-asbestosis advanced previously silico-asbestosis early	Nil
Silico-asbestosis plus tuberculosis previously normal	Nil
Silico-asbestosis advanced previously silicosis early	Nil
Silico-asbestosis advanced with tuberculosis previously silico-asbestosis early	Nil
	3,941

These 1966 figures, together with the figures for the previous years, are shown in the table annexed hereto. Graphs are also attached illustrating the trend of examinations since 1940.

Analyses of Examinations.—In explanation of the examination figures, I desire to make the following comments:—

Normal, Etc.—These numbered 3,411 or 86.56% of the men examined and include men having first class lives or suffering from fibrosis only. The figures for the previous year being 3,770 or 87.39%.

Early Silicosis.—These numbered 495 of which 26 were new cases and 469 had previously been reported, the figures for 1965 being 53 and 459 respectively. Early silicotics represent 12.56% of the men examined, the percentage for the previous year being 11.87%.

Advanced Silicosis.—There were 14 cases reported all of which advanced from early silicosis during the year. Advanced silicotics represent 0.36% of the men examined, the percentage for the previous year being 0.14%.

Silicosis Plus Tuberculosis.—Four cases were reported which was three more than reported in 1965.

Tuberculosis Only.—One case was reported compared with five in 1965.

Asbestosis.—Seven cases of early asbestosis were reported. One was a new case and six had previously been reported.

Silico Asbestosis.—Nine cases were reported of which three were new cases.

Mines Regulation Act.

Total Examinations.—Examinations under the Mines Regulation Act totalled 2,908. These were in addition to 3,941 under the Mine Workers' Relief Act. There was an increase of 532 examinations under this Act in 1966 as compared with those in 1965. Of the total of 2,908 men examined 2,666 were new applicants and 242 were re-examinees.

Analyses of Examinations.—Particulars of examinations are as follows:—

New Applicants.—

Normal	2,647
Silicosis early	4
Early silicosis with tuberculosis	Nil
Tuberculosis	7
Other conditions	8
Total:	2,666

Re-Examinees.—

Normal	234
Silicosis early	1
Tuberculosis	4
Other conditions	3
Total:	242

These men had been previously examined and some were in the industry prior to this examination.

Health Certificates Issued to New Applicants and Re-Examinees.

The following health certificates were issued under the Mines Regulation Act:—

Initial Certificates (Form 2)	2,879
Temporary Rejection Certificates (Form 3)	3
Rejection Certificate (Form 4)	22
Re-admission Certificates (Form 5)	Nil
Special Certificates (Form 9)	2
No certificate issued	2
	2,908

Miners' Phthisis Act.

The amount of compensation paid during the year was $14,653.67 compared with $15,675.57 for the previous year.

The number of beneficiaries under the Act as on 31st December, 1966 was 65 being 6 ex-miners and 59 widows.

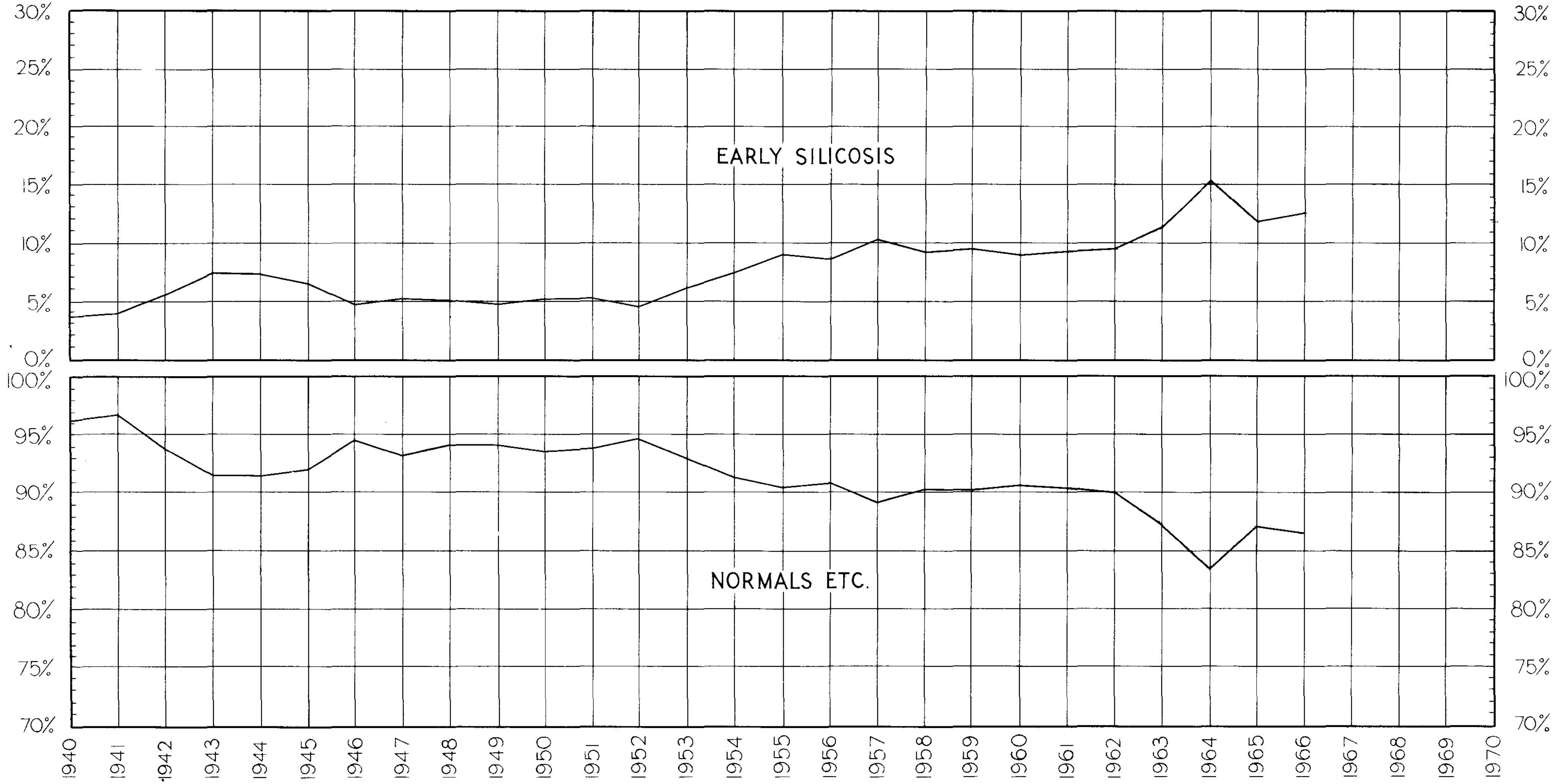
A. L. DAY,

Superintendent Mines Workers' Relief Act and Chairman Miners' Phthisis Board.

PERIODICAL EXAMINATION OF MINE WORKERS

GRAPH Nº 1

Showing Percentages of Normals and Early Silicotics from 1940 onwards



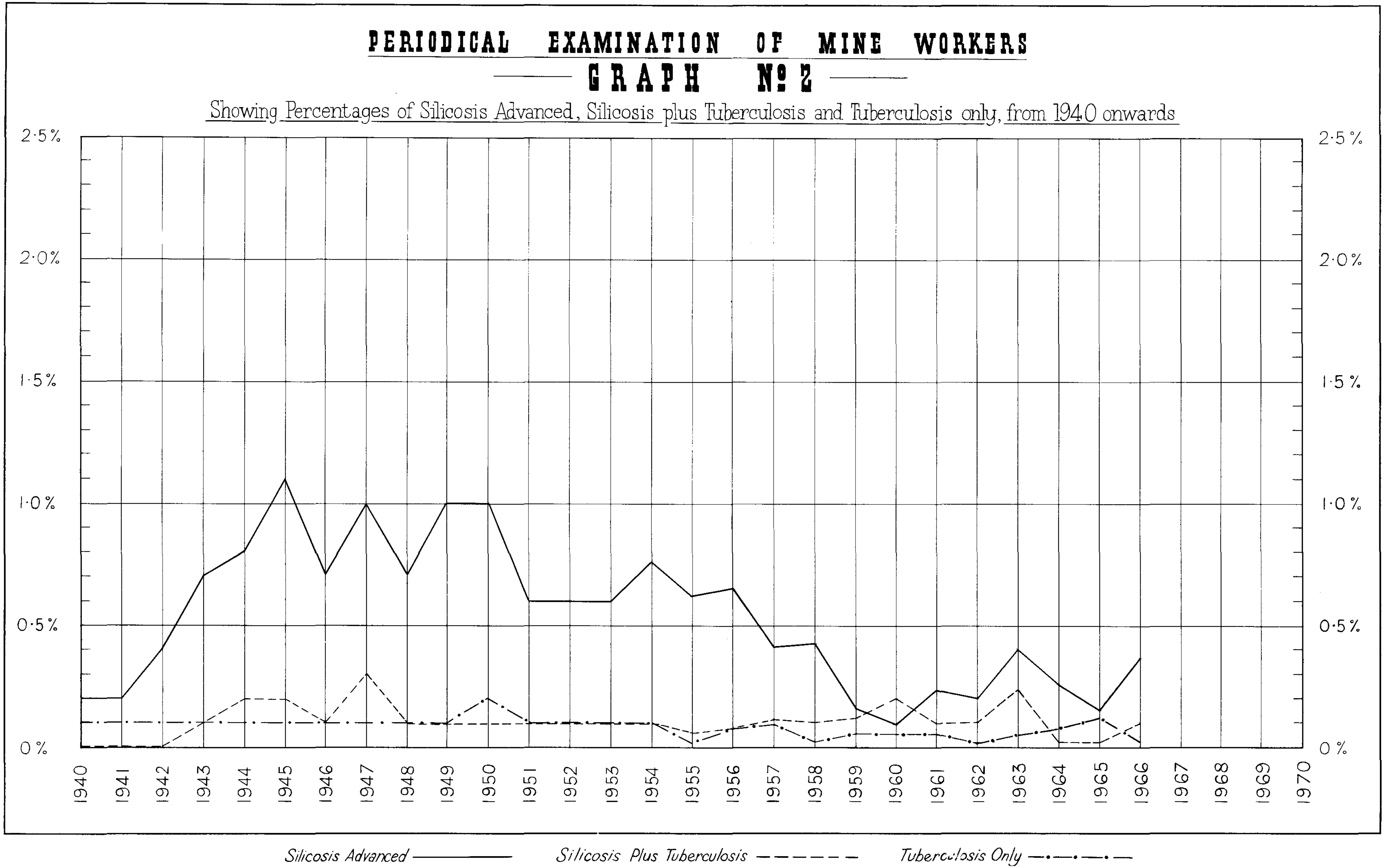

PERIODICAL EXAMINATION OF MINE WORKERS
GRAPH Nº 2
Showing Percentages of Silicosis Advanced, Silicosis plus Tuberculosis and Tuberculosis only, from 1940 onwards
2·5%
2·0%
1·5%
1·0%
0·5%
0%
1940
1941
1942
1943
1944
1945
1946
1947
1948
1949
1950
1951
1952
1953
1954
1955
1956
1957
1958
1959
1960
1961
1962
1963
1964
1965
1966
1967
1968
1969
1970
Silicosis Advanced
Silicosis Plus Tuberculosis
Tuberculosis Only

TABLE SHOWING RESULTS OF PERIODICAL EXAMINATION OF MINE WORKERS FROM INCEPTION OF EXAMINATIONS (1925).

	Normal		Silicosis Early				Silicosis Advanced					Silicosis plus Tuberculosis					Tuberculosis Only		Asbestosis									
Year	Total	Per Cent.	Previously reported as Normal etc.	Previously reported as Silicosis Early	Total	Per Cent.	Previously reported as Normal etc.	Previously reported as Silicosis Early	Previously reported as Silicosis Advanced	Total	Per Cent.	Previously reported as Normal etc.	Previously reported as Silicosis Early	Previously reported as Silicosis Advanced	Total	Per Cent.	Total	Per Cent.	Asbestosis early previously normal	Asbestosis early previously asbestosis early	Asbestosis advanced previously normal	Asbestosis advanced previously asbestosis early	Asbestosis advanced previously asbestosis advanced	Asbestosis plus tuberculosis previously normal	Asbestosis plus tuberculosis previously asbestosis	Total	Per Cent.	Total
1925 } 1926 }	3,239	80·5	....	....	459	11·4	....	....	....	183	4·5	....	....	....	131	3·3	11	0·3	....	....	....	....	....	....	....	....	....	4,023
1927	3,116	83·6	33	348	381	10·2	8	....	85	93	2·5	39	27	62	128	3·4	10	0·3	....	....	....	....	....	....	....	....	....	3,728
1928	2,977	85·5	59	303	362	10·4	3	16	79	98	2·8	18	14	10	42	1·2	4	0·1	....	....	....	....	....	....	....	....	....	3,483
1929	2,120	81·9	102	224	326	12·6	....	34	60	94	3·6	8	14	19	41	1·6	7	0·3	....	....	....	....	....	....	....	....	....	2,588
1930	2,785	81·9	136	247	383	11·3	2	22	43	67	2·0	8	60	46	114	3·3	50	1·5	....	....	....	....	....	....	....	....	....	3,399
1931	2,530	84·0	94	252	346	11·5	....	18	35	53	1·8	4	35	19	58	1·9	25	·8	....	....	....	....	....	....	....	....	....	3,012
1932	3,835	89·5	35	338	373	8·7	....	6	47	53	1·2	3	9	4	16	·4	8	·2	....	....	....	....	....	....	....	....	....	4,285
1933	2,920	86·5	57	322	379	11·2	1	15	44	60	1·8	2	9	4	15	·4	3	·1	....	....	....	....	....	....	....	....	....	3,377
1934	5,140	92·4	54	315	369	6·6	1	24	12	37	·7	6	6	....	12	·2	5	·1	....	....	....	....	....	....	....	....	....	5,563
1935	4,437	92·3	35	303	338	7·0	....	24	2	26	·6	....	5	....	5	·1	2	·0	....	....	....	....	....	....	....	....	....	4,808
1936	6,972	94·7	29	323	352	4·8	1	15	4	20	·3	3	8	....	11	·1	8	·1	....	....	....	....	....	....	....	....	....	7,363
1937	7,487	95·4	15	319	334	4·3	....	14	4	18	·2	1	10	....	11	·1	2	·0	....	....	....	....	....	....	....	....	....	7,852
1938	6,833	95·7	13	266	279	3·9	....	15	2	17	·2	1	8	....	9	·1	3	·0	....	....	....	....	....	....	....	....	....	7,141
1939	6,670	95·6	18	264	282	4·0	....	7	3	10	·1	1	9	1	11	·2	2	·0	....	....	....	....	....	....	....	....	....	6,975
1940	7,023	96·2	12	245	257	3·5	....	10	1	11	·2	....	4	....	4	·0	4	·0	....	....	....	....	....	....	....	....	....	7,299
1941	6,840	95·8	32	248	280	3·9	....	11	3	14	·2	....	....	....	....	....	7	·1	....	....	....	....	....	....	....	....	....	7,141
1942	5,469	93·9	61	264	325	5·6	....	20	5	25	·4	....	2	....	2	·0	3	·1	....	....	....	....	....	....	....	....	....	5,824
1943	3,932	91·5	63	262	325	7·6	....	25	7	32	·7	....	5	....	5	·1	4	·1	....	....	....	....	....	....	....	....	....	4,298
1944	4,079	91·5	70	270	340	7·5	....	21	14	35	·8	1	7	....	8	·2	6	·1	....	....	....	....	....	....	....	....	....	4,468
1945	3,071	92·1	54	166	220	6·6	....	26	10	36	1·1	3	2	....	5	·2	2	·1	....	....	....	....	....	....	....	....	....	3,334
1946	5,294	94·4	89	172	261	4·7	1	36	2	39	·7	3	1	2	6	·1	6	·1	....	....	....	....	....	....	....	....	....	5,606
1947	6,021	93·3	101	237	338	5·2	....	49	9	58	1·0	13	11	1	25	·3	8	·1	....	....	....	....	....	....	....	....	....	6,450
1948	4,827	94·0	24	239	263	5·1	....	18	17	35	·7	1	3	....	4	·1	5	·1	....	....	....	....	....	....	....	....	....	5,134
1949	5,162	94·0	24	239	263	4·8	....	20	31	51	1·0	3	2	1	6	·1	7	·1	....	....	....	....	....	....	....	....	....	5,489
1950	5,077	93·6	14	269	283	5·2	....	14	41	55	1·0	....	1	2	3	·1	8	·2	....	....	....	....	....	....	....	....	....	5,426
1951	4,642	93·9	13	248	261	5·3	....	9	20	29	·6	....	4	2	6	·1	4	·1	....	....	....	....	....	....	....	....	....	4,942
1952	5,073	94·6	8	234	242	4·5	....	4	31	35	·6	....	2	....	2	·1	7	·1	....	....	....	....	....	....	....	....	....	5,359
1953	4,474	93·03	74	225	299	6·22	....	8	24	32	·6	....	2	....	2	·1	2	·1	....	....	....	....	....	....	....	....	....	4,809
1954	5,142	91·33	154	275	429	7·62	....	22	21	43	·76	1	6	2	9	·1	7	·1	....	....	....	....	....	....	....	....	....	5,630
1955	4,559	90·40	63	386	449	8·90	....	9	22	31	·62	1	1	1	3	·06	1	·02	Segregation of asbestosis diagnoses commenced in 1959									5,043
1956	4,600	90·78	25	401	426	8·41	....	8	25	33	·65	1	3	....	4	·08	4	·08	....	....	....	....	....	....	....	....	....	5,067
1957	3,925	89·08	30	424	454	10·30	....	8	10	18	·41	1	4	....	5	·12	4	·09	....	....	....	....	....	....	....	....	....	4,406
1958	5,154	90·20	46	483	529	9·26	....	15	9	24	·42	....	6	....	6	·10	1	·02	....	....	....	....	....	....	....	....	....	5,714
1959	5,242	90·10	66	485	551	9·47	....	9	....	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
1964	3,484	83·85	64	561	625	15·04	....	9	1	10	·24	....	1	....	1	·02	2	·05	13	17	....	2	....	....	1	33	·80	4,155
1965	3,770	87·39	53	459	512	11·87	....	6	....	6	·14	....	1	....	1	·02	5	·12	5	15	....	....	....	....	....	20	.46	4,314
1966	3,411	86·56	26	469	495	12·56	....	14	....	14	·36	3	1	....	4	·10	1	·02	4	12	....	....	....	....	....	16	·40	3,941

DIVISION X

Report of the Chief Draftsman for the Year 1966

Under Secretary for Mines.

For the information of the Honourable the Minister I herewith submit my report on the operation of the Survey and Mapping Branch for the year ended 31st December, 1966.

STAFF

The membership of the staff now totals 49 officers comprising 45 males and 4 females.

There were four resignations (two male and two female) to mining companies during the past twelve months but replacements have been appointed.

Cadet Cartographers, J. Brookman, P. Carroll, P. Taylor and R. Hammond became eligible for permanent appointment while the remaining cadets were successful in their respective examinations.

Cadastral surveying generally has been increased throughout the State with particular emphasis on the Pilbara region.

Itemised reports of the activities of the various sections of the branch are appended hereto.

A. A. HALL,
Chief Draftsman.

SURVEYS

Contract surveys to the value of $62,524-87 were negotiated and carried out during the year at the following centres:—

South West Mineral Field.

Capel	Wanneroo
Marchagee	Byford

Pilbara Goldfield.

Moolyella	Breens
Nimingarra	Hartigan
Port Hedland	Talga Talga
Tabba Tabba	Hillside
Carlindi	Elys
Shaw River	Coondina
McPhees Hill	Coomba Well
Wodgina	Pilga
Pinga Well	Tambina
Cooglegong	Tambourah Creek
Split Rock	Bamboo
Marble Bar	
Coolyia Creek	

East Coolgardie Goldfield.

Kalgoorlie

Coolgardie Goldfield.

Ritchies	Coolgardie
Camel Farm	Northlander

Yilgarn Goldfield.

Karalee

Dundas Goldfield.

Norseman	Princess Royal
Lake Cowan	

Northampton Mineral Field.

Galena	Northampton

Collie River Mineral Field.

Collie

Greenbushes Mineral Field.

Greenbushes

West Pilbara Goldfield.

Mt. Tom Price

Gascoyne Goldfield.

Peron Peninsula

Peak Hill Goldfield.

Ilgararie	Horseshoe
Kumarina	

Outside Proclaimed Goldfield.

Warburton Range	Wingellina

The total number of surveys completed during the year were 478 compared with an average over the three previous years of 177.

The bulk of the survey work was done in the tinfields centred around Marble Bar, where extensive ground had been pegged under title of Mineral or Dredging Claim. Surveys performed in these areas accurately traverse out the form of the drainage pattern and as such, form an invaluable means of control for mapping.

Sections 1-5 and 8 of the iron ore Mineral Lease 4SA at Mt. Tom Price in the Hamersley Ranges were surveyed during the year.

The survey of the Geraldton Explosive reserve and the magazine sites thereon, were performed for the Explosives Branch.

SURVEY EXAMINATION

Diagrams of surveys were drawn and examined. Original and duplicate plans were prepared and lease instruments and diagrams of surrender and resumptions were prepared as required.

Survey instructions and necessary information relating to survey details were supplied to surveyors in the field.

GEODETIC

Calculations for the laying down on the Transverse Mercator Projection of our Standard plans were carried out for the following sheets:—

F50-3-9	Whim Creek 80
F50-3-9	Whim Creek 20-7
F50-3-9	Whim Creek 20-9
F50-3-9	Whim Creek 20-10
F50-3-9	Whim Creek 20-11
F50-3-9	Whim Creek 20-16

F50-14-2551 III	Capricorn 1:50,000
F50-14-2251 II	Stockyard Creek 1:50,000
F50-14-2251 I	Dead Finish 1:50,000
F50-14-2051 IV	Telfer River 1:50,000
F50-10-2152 II	Kooline 1:50,000
F50-10-2152 III	Mt. Clement 1:50,000
F50-10-2052 III	Glenflorrie 1:50,000
F50-10-2052 II	Thowagee 1:50,000
F50-9-1952 II	Uaroo 1:50,000
F50-9-1952 I	Nanutarra 1:50,000
F50-9-1952 IV	Victoria 1:50,000
F50-10-2152 IV	Wyloo 1:50,000
F50-10-2152 I	De Courcey 1:50,000
F50-6-2054 I	Yarraloola 1:50,000
F50-10-2153 IV	Cane River 1:50,000
F50-6-2154 III	Red Hill 1:50,000
F50-6-2154 IV	Yerra Bluff 1:50,000
F50-9-1593 I	Ironstone 1:50,000
H51-9-2936 III	Mt. Walter 20-6
H51-9-2936 III	Mt. Walter 1:50,000
H51-9-2936 IV	Breakaway 1:50,000
F50-11-2452 II	Mt. Tom Price 1:50,000
F50-11-2452 I	Bunjinah 1:50,000
F50-11-2452 III	Weelarra 1:50,000
F50-11-2452 IV	Mt. Lionel 1:50,000

MAPPING.

593 Technical plans were prepared and drawn for Geological Surveys together with 5,633 prints and duplicates from various originals.

1:250,000 Maps.

The printing of Roebourne, Roy Hill, Mt. Bruce and Newman sheets was finalised whilst Widgiemooltha sheet was forwarded for printing.

The fair drawing of Pyramid sheet was completed and drafting proceeded with on Robertson, Edmund, Busselton-Augusta, Turee Creek, Yarraloola and Kalgoorlie.

Bulletins.

Bulletin 117. "The Geology and Iron Deposits of the Hamersley Range Area" with 11 plates and 2 figures and involving considerable drafting time was completed and forwarded for printing.

Bulletin 118. "The Devonian Reef Complex of the Canning Basin" consisting of 5 sheet and 7 plates was also a major assignment and was virtually completed at the close of the year.

State Map 1:2,500,000.

The new State Map based on Albers Projection has been compiled, all type has been received and scribing is proceeding.

Standard Compilations—Transverse Mercator.

A concerted effort with the staff available produced 34 plans which may give some impetus to this large and important programme of recording basic mining surveys.

Standard Mapping 1:50,000.

Consolidating a scheme which has been partially in vogue for some years, the practice of press printing of mining lease maps at the Government Printer has been virtually discontinued. Maps are now produced as a Master transparency from which up to date paper copies are made at short notice as required. This method saves, time, money and storage space whilst the information is up to date and the whole operation is produced in this Branch.

MISCELLANEOUS.

Various plans, diagrams, certificates, time tables, etc., were produced for the School of Mines, Chemical Laboratories, Machinery and Explosives Branch, etc.

PLAN PRINTING AND PHOTO SECTION.

Dyeline prints and duplicates of all types produced during the year amounted to 30,583 copies. There is a growing necessity for a trained photographic process officer in this section.

CONFERENCE.

The Interstate Conference of Senior State and Federal Officers employed on Geological Cartography was held in Perth during October. Invaluable data on this highly developed phase of mapping was freely given and exchanged and once again proved the value of personal collaboration.

PUBLIC PLAN SECTION.

During the year the following applications were received and charted on public plans.

Mining Tenements	1,437
Temporary Reserves	390
Licenses to Prospect (Oil)	25
Permits to Explore (Oil)	18
Oil Leases	2

A total of 1559 plans were produced during the year, of which 1370 were for public sale purposes ($2,435.30). In addition numerous special purpose plans were prepared for Departmental use.

Six hundred and Fifty Three searches to determine land tenure and mineral ownership have been carried out, an increase of 50% on 1965 and 100% on 1964 and still rapidly expanding.

The following provisional 1:50,000 Series plans have been compiled and introduced into the public plan system.

R 712 Sheet 4461—11 Palm Springs

R 712 Sheet 4461—111 Rock Hole

Old series lithos—L116 Mt. Gibson was re-aligned and redrawn together with two new lithos adjoining same viz. L123, L124.

MINING STATISTICS

to 31st December, 1966

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TABLE 1

PRODUCTION OF GOLD AND SILVER FROM ALL SOURCES, SHOWING IN FINE OUNCES THE OUTPUT AS REPORTED TO THE MINES DEPARTMENT DURING 1966, AND THE TOTAL PRODUCTION TO DATE.

(*Note.*—Lease numbers in brackets indicate that the holding was *voided* during the year.)

(*Note.*—* Denotes mainly derived from treatment of tailings. † Denotes mainly derived from **Lead Ore.** ‡ Denotes mainly derived from Copper Ore. § Concentrates.)

Kimberley Goldfield.

Mining Centre	Number of Lease	Registered Name of Company or Lease	Total for 1966					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	....	....	....	10.14	....	....	....	120.00	31.78	....
		Voided Leases	....	....	....	....	....	....	....	423.00	477.76	....
		Sundry Claims	....	....	....	....	....	27.73	....	217.05	179.57	12.64
Mary	....	Voided Leases	....	....	....	....	....	82.66	951.52	399.00	210.03	....
		Sundry Claims	....	....	....	....	....	....	14.36	46.85	53.66	....
Mt. Dockrell	....	Voided Leases	....	....	....	....	....	9.17	13.66	1,173.70	1,206.09	93.00
		Sundry Claims	....	....	....	....	....	18.89	31.31	160.00	89.64	....
Panton	....	Voided Leases	....	....	....	....	....	....	....	42.95	140.47	....
		Sundry Claims	....	....	....	....	....	....	6.28	6.15	18.01	....
Ruby Creek	....	Voided Leases	....	....	....	....	....	....	16.05	16,031.45	11,366.29	2.14
		Sundry Claims	....	....	....	....	....	12.71	....	281.25	183.30	....
	From Goldfield Generally :—											
	Sundry Claims	....	....	....	....	....	....	....	....	....	....	†20.98
	Reported by Banks and Gold Dealers	....	....	7.97	....	....	....	8,920.90	1,994.63	.75	8.15	....
		Total	....	**7.97**	....	**10.14**	....	**9,079.68**	**3,035.43**	**22,931.90**	**17,292.01**	**128.76**

West Kimberley Goldfield.

Mining Centre	Number of Lease	Registered Name of Company or Lease	Total for 1966: Alluvial	Dollied and Specimens	Ore treated	Gold therefrom	Silver	Total Production: Alluvial	Dollied and Specimens	Ore treated	Gold therefrom	Silver
Napier Range	M.C. 29	Devonian Silver Lead Mine	....	....	....	....	†4,119.98	....	....	....	....	†37,317.55
	From Goldfield generally :—											
	Sundry Claims	....	....	....	....	....	....	....	13.76	1.00	2.49	....
	Reported by Banks and Gold Dealers	....	....	....	....	....	....	1.30	10.92	....	....	....
		Total	....	....	....	....	**†4,119.98**	**1.30**	**24.68**	**1.00**	**2.49**	**†37,317.55**

Pilbara Goldfield.

MARBLE BAR DISTRICT.

Bamboo Creek	G.M.L. 1120	Bamboo Queen	....	....	....	....	....	....	....	88.50	30.99	.34
	1118	Kitchener	....	....	50.75	71.98	....	....	....	369.75	576.70	3.53
	1203	Mt. Prophecy	....	....	570.50	667.03	47.78	....	....	1,338.25	993.86	74.78
	1095 (1096) (1097)	Mt. Prophecy Leases	....	....	....	....	....	....	24.50	3,053.00	1,096.72	49.63
	1072	Princess May	....	....	....	....	....	....	....	92.50	24.27	....
	924	True Blue	....	....	....	....	....	.62	....	4,671.25	114.64	.22
		Voided Leases	....	....	....	....	....	13.54	572.09	59,841.35	62,578.94	304.99
		Sundry Claims	....	....	....	....	....	8.97	307.83	5,208.85	3,034.45	7.21
Boodalyerrie		Voided Leases	....	....	....	....	....	....	292.07	120.25	587.86	....
		Sundry Claims	....	....	....	....	....	....	7.16	....	....	....
Braeside		Sundry Claims	....	....	....	....	....	....	....	....	....	†25,853.75
Lalla Rookh		Voided Leases	....	....	....	....	....	....	4.78	3,612.00	4,696.33	574.01
		Sundry Claims	....	....	6.25	11.00	....	....	....	8,145.50	7,902.02	....
Marble Bar	G.M.L. 930 (956)	Alexander Leases	....	....	37.75	2.77	.13	....	....	392.25	123.71	.94
	930	Alexander	....	....	....	....	....	....	....	640.00	114.59	....
	1094	Blue Bar	....	....	88.00	18.43	.62	....	....	1,550.50	202.09	1.10
	927, 934, 928....	Halley's Comet Leases	....	....	....	....	....	....	....	6,360.00	6,390.33	680.36
	927, 934	Prior to transfer to present holders	....	....	....	....	....	....	....	355.00	1,002.94	....
	1209	Ironclad	....	....	....	....	....	....	....	156.00	12.70	.20
	1121	Little Portree	....	....	....	....	....	....	....	103.00	66.88	6.93
		Voided Leases	....	....	....	....	....	45.98	199.09	165,732.99	150,731.56	595.61
		Sundry Claims	....	....	38.50	1.33	....	67.08	255.30	21,736.54	12,896.79	10.96
North Pole	1122 (1123) (1124)	Normay Leases	....	....	....	....	....	....	....	1,685.00	1,435.98	1,755.28
		Voided Leases	....	....	....	....	....	....	....	4,339.00	1,930.51	260.08
		Sundry Claims	....	....	....	....	....	....	....	669.75	298.62	15.82
North Shaw		Voided Leases	....	....	....	....	....	7.53	....	1,072.45	996.29	....
		Sundry Claims	....	....	....	....	....	128.39	579.91	179.75	121.72	.05
Pilgangoora	1208	Birthday Gift	....	....	....	....	....	....	....	103.25	115.00	....
	1211	Stirrup Iron....	....	....	21.25	14.43	4.94	....	....	21.25	14.43	4.94
		Voided Leases	....	....	....	....	....	16.65	....	2,279.00	407.57	....
		Sundry Claims	....	....	26.50	17.11	.21	161.08	47.76	598.10	318.27	.25
Sharks	1082, etc.	Table Top Leases	....	....	....	....	....	....	....	1,082.75	594.97	17.28
		Voided Leases	....	....	....	....	....	1.43	....	1,739.50	1,969.65	1.16
		Sundry Claims	....	....	....	....	....	163.14	47.93	1,159.50	1,675.34	.97
Talga Talga		Voided Leases	....	....	....	....	....	....	93.15	1,799.00	1,760.68	....
		Sundry Claims	....	....	....	....	....	76.17	85.18	2,013.65	1,509.26	.70
Tambourah		Voided Leases	....	....	....	....	....	....	73.90	1,603.50	1,886.22	....
		Sundry Claims	....	....				89.52	294.75	3,742.25	2,689.78	

Table I.—*Production of Gold and Silver from all sources, etc.*—continued.

Mining Centre	Number of Lease	Registered Name of Company or Lease	Total for 1966					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	....	....	51.25	.69	....	....	....	400.75	28.02	2.36
		Voided Leases	....	....	....	....	....	....	16.99	17,749.30	19,645.44	23.70
		Sundry Claims	....	....	....	....	....	70.98	623.67	6,632.79	4,247.38	.08
Western Shaw	....	Voided Leases	....	....	....	....	....	....	....	1,222.50	957.80	....
		Sundry Claims	....	....	....	....	....	22.34	67.47	71.50	81.49	....
Wodgina	....	Sundry Claims	....	....	....	....	....	....	43.37	.50	....	3.25
Wyman's Well	1215	Kathleen	....	....	121.00	11.77	....	....	....	121.00	11.77	....
	1084	New Copenhagen	....	....	....	....	....	....	....	770.55	165.52	4.34
		Voided Leases	....	....	....	....	....	....	42.86	2,977.29	1,258.44	....
		Sundry Claims	....	....	....	....	....	4.47	51.52	2,732.71	1,324.64	1.47
Yandicoogina	....	Voided Leases	....	....	....	....	....	....	140.76	3,159.20	6,218.83	....
		Sundry Claims	....	....	....	....	....	4.32	239.89	622.25	682.47	45.96
From District generally :—												
Sundry Parcels treated at :												
State Battery, Bamboo Creek			....	....	....	....	....	....	....	40.00	*12,156.01	371.34
State Battery, Marble Bar			....	....	....	87.49	11.61	....	....	12.00	*13,038.53	163.36
A. Crowe & J. Olive (L.T.T. 1602H)			....	....	....	....	....	....	....	169.00	*9.71	.19
R. K. Leslie (L.T.T. 1632H)			....	....	151.25	*12.64	....	....	....	151.25	*12.64	....
Various Works			....	....	....	....	....	....	....	380.95	*1,924.48	5.96
Reported by Banks and Gold Dealers			....	....	....	....	....	14,628.26	457.21	....	15.41	2,224.95
		Total	....	....	**1,163.00**	**916.67**	**65.29**	**15,510.47**	**4,569.14**	**344,868.72**	**332,682.24**	**33,068.05**
		NULLAGINE DISTRICT.										
Eastern Creek	....	Voided Leases	....	....	....	....	....	8.96	8.19	5,594.00	9,854.21	14.76
		Sundry Claims	....	....	....	....	....	....	12.74	1,481.10	1,627.92	17.02
Elsie	....	Voided Leases	....	....	....	....	....	....	....	586.25	1,675.91	....
		Sundry Claims	....	....	....	....	....	....	8.28	58.00	188.08	....
McPhee's Creek	....	Voided Leases	....	....	....	....	....	....	....	113.00	137.92	....
		Sundry Claims	....	....	....	....	....	....	....	134.00	197.09	....

Middle Creek	G.M.L. 229L .... 231L, etc.	Barton	....	....	....	....	....	1.22	....	9,566.75	4,655.81	38.24
		North West Mining N.L.	....	....	....	....	....	....	....	9,782.07	6,174.22	....
		Prior to transfer to present holders	....	....	....	....	....	....	....	53,391.41	32,009.01	10.99
		Voided Leases	....	....	....	....	....	....	1.02	18,938.15	11,754.34	8.37
		Sundry Claims	....	....	....	....	....	....	18.69	6,792.60	2,645.65	2.38
Mosquito Creek	331L	Ard Patrick	....	....	....	....	....	10.80	....	78.00	19.75	....
		Voided Leases	....	....	....	....	....	1.07	30.12	8,392.30	12,839.13	....
		Sundry Claims	....	....	....	....	....	....	181.64	3,707.44	3,789.21	....
Nullagine	292L	Alice	....	....	....	....	....	3.85	1,162.49	138.85	331.29	63.61
		Voided Leases	....	....	....	....	....	....	599.59	9,393.75	13,457.00	41.07
		Sundry Claims	....	....	....	....	....	321.36	689.71	6,689.45	10,577.95	18.62
Spinaway Well Twenty Mile Sandy	314L	Copper Hills Copper Mine	....	....	....	....	....	....	....	....	‡15.44	‡483.78
		Voided Leases	....	....	....	....	....	....	16.97	7,243.70	9,008.65	371.70
		Sundry Claims	....	....	....	....	....	33.10	30.50	7,815.85	6,286.11	2.76
		From District generally :—										
		Sundry Parcels treated at :										
		Barton Battery	....	....	....	....	....	....	....	....	*45.19	....
		Various Works	....	....	....	....	....	3.89	2.23	145.75	*8,119.30	1.37
		Reported by Banks and Gold Dealers	....	....	....	....	....	10,125.28	147.52	....	48.03	6.12
		Total						10,509.53	2,909.69	150,042.42	135,457.21	1,080.79

West Pilbara Goldfield.

Croydon	....	Voided Leases	....	....	....	....	....	....	....	8.00	5.44	....
Hong Kong	....	Voided Leases	....	....	....	....	....	....	....	331.00	442.45	....
		Sundry Claims	....	....	....	....	....	21.40	.02	9.00	3.15	....
Lower Nicol	G.M.L. 177	Swelpme	....	....	....	....	....	....	....	119.00	7.02	.60
		Voided Leases	....	....	....	....	....	....	1.10	653.20	402.22	....
		Sundry Claims	....	....	....	....	....	10.44	2.71	99.00	35.16	.40
Mallina	....	Voided Leases	....	....	....	....	....	....	....	141.60	128.44	....
Nicol	....	Voided Leases	....	....	....	....	....	....	....	30.00	11.47	....
Pilbara	....	Voided Leases	....	....	....	....	....	9.90	48.12	267.00	432.84	....
		Sundry Claims	....	....	....	....	....	1.11	86.24	163.00	255.42	....
Roebourne	....	Voided Leases	....	....	....	....	....	....	....	2,396.86	1,424.04	385.15
		Sundry Claims	....	....	....	....	....	15.47	3.29	1,946.85	817.89	130.21
Station Peak	....	Voided Leases	....	....	....	....	....	177.74	41.37	11,016.00	11,388.18	.08
		Sundry Claims	....	....	....	....	....	.69	....	86.50	77.23	....
Towranna	....	Voided Leases	....	....	....	....	....	....	2.62	3,965.80	5,187.51	....
		Sundry Claims	....	....	....	....	....	....	....	22.00	12.35	....
Upper Nicol	....	Sundry Claims	....	....	....	....	....	....	....	6.50	2.57	....
Weerianna	....	Voided Leases	....	....	....	....	....	....	....	3,200.15	3,214.45	....
		Sundry Claims	....	....	....	....	....	....	....	336.00	135.26	1.29

Table I.—*Production of Gold and Silver from all sources, etc.*—continued.

WEST PILBARA GOLDFIELD—continued.

Mining Centre	Number of Lease	Registered Name of Company or Lease	Total for 1966 Alluvial (Fine ozs.)	Total for 1966 Dollied and Specimens (Fine ozs.)	Total for 1966 Ore treated (Tons (2,240 lb.))	Total for 1966 Gold therefrom (Fine ozs.)	Total for 1966 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.)
Whim Creek	....	Voided Leases	....	....	....	....	....	....	....	....	....	‡883.80
		From Goldfield generally :—										
		Sundry Parcels treated at :										
		Various Works	....	....	....	....	....	....	....	....	*102.39	4.90
		Sundry Claims	....	....	....	....	....	....	11.77	....	....	‡503.36
		Reported by Banks and Gold Dealers	....	....	....	....	....	6,102.62	177.50	103.50	231.54	.87
		Total	....	....	....	....	....	**6,339.37**	**374.74**	**24,900.96**	**24,317.02**	**1,910.66**

Ashburton Goldfield.

Mining Centre	Number of Lease	Registered Name of Company or Lease	Total for 1966 Alluvial (Fine ozs.)	Total for 1966 Dollied and Specimens (Fine ozs.)	Total for 1966 Ore treated (Tons (2,240 lb.))	Total for 1966 Gold therefrom (Fine ozs.)	Total for 1966 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.)
Belvedere	....	Voided Leases	....	....	....	....	....	....	9.88	1,560.00	435.86	176.48
Dead Finish	....	Voided Leases	....	....	....	....	....	....	....	1,699.00	874.60	.03
		Sundry Claims	....	....	....	....	....	....	11.89	104.25	245.08	....
Linden Station	....	Sundry Claims	....	....	....	....	....	....	....	128.35	203.51	....
Melrose	....	Voided Leases	....	....	....	....	....	....	....	2,704.00	840.26	213.11
		Sundry Claims	....	....	....	....	....	12.41	21.88	562.00	262.78	6.40
Mt. Edith	....	Sundry Claims	....	....	....	....	....	....	....	5.00	3.97	....
Mt. Mortimer	....	Sundry Claims	....	....	....	....	....	364.63	315.64	44.50	40.25	74.47
Uaroo	....	Voided Leases	....	....	....	....	....	....	....	....	....	†7,713.22
		From Goldfield generally :—										
		Sundry Claims (Lead Ores)	....	....	....	....	....	....	....	....	....	†33,787.67
		Reported by Banks and Gold Dealers	....	....	....	....	....	8,891.48	123.17	....	7.12	....
		Total	....	....	....	....	....	**9,268.52**	**482.46**	**6,807.10**	**2,913.43**	**41,971.38**

Gascoyne Goldfield.

Mining Centre	Number of Lease	Registered Name of Company or Lease	Total for 1966 Alluvial (Fine ozs.)	Total for 1966 Dollied and Specimens (Fine ozs.)	Total for 1966 Ore treated (Tons (2,240 lb.))	Total for 1966 Gold therefrom (Fine ozs.)	Total for 1966 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.)
Bangemall	....	Voided Leases	....	....	....	....	....	....	6.22	350.70	313.82	....
		Sundry Claims	....	....	....	....	....	88.97	33.55	36.30	203.47	....
Mangaroon Station	G.M.L. 46	Star of Mangaroon	....	....	143.00	350.08	16.24	....	3.50	701.75	1,637.38	60.25
		Sundry Claims	....	....	....	....	....	....	49.09	97.00	376.12	26.92
		From Goldfield generally :—										
		Reported by Banks and Gold Dealers	....	....	....	....	....	609.52	28.97	....	2.56	....
		Total	....	....	**143.00**	**350.08**	**16.24**	**698.49**	**121.33**	**1,185.75**	**2,533.35**	**87.17**

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
		Prior to transfer to present holders	....	....	....	....	....	....	....	139,786.00	23,765.24	1,407.05
		Voided Leases	....	....	....	....	....	15.57	1,975.37	5,654.38	2,818.56	2.00
		Sundry Claims	....	....	....	....	....	20.12	829.58	2,201.35	809.20	1.14
Jimblebar	....	Voided Leases	....	....	....	....	....	....	172.75	7,526.25	2,561.95	.58
		Sundry Claims	....	....	....	....	....	13.79	65.95	1,048.05	574.16	....
Mt. Fraser	....	Voided Leases	....	....	....	....	....	....	....	399.00	336.28	....
		Sundry Claims	....	....	....	....	....	88.28	40.61	480.75	460.12	....
Mt. Seabrook	....	Voided Leases	....	....	....	....	....	....	5.05	620.25	428.26	....
		Sundry Claims	....	....	....	....	....	....	....	1,089.35	803.12	....
Peak Hill	G.M.L. 584P	Dazzle Star	....	6.18	....	....	.17	....	6.18	329.00	99.97	.67
		Voided Leases	....	....	....	....	....	32.28	1,083.61	562,300.28	253,909.89	2,302.11
		Sundry Claims	....	....	....	....	....	61.51	377.54	35,365.35	9,030.99	5.35
Ravelstone	....	Voided Leases	....	....	....	....	....	....	101.64	4,219.85	3,117.68	....
		Sundry Claims	....	....	....	....	....	....	....	553.60	283.17	....
Wilgeena	....	Voided Leases	....	....	....	....	....	....	23.54	230.50	156.25	....
Wilthorpe	....	Voided Leases	....	....	....	....	....	....	....	47.00	20.93	....
		Sundry Claims	....	....	....	....	....	....	....	89.00	25.71	....
Yowereena	....	Voided Leases	....	....	....	....	....	....	....	19.50	36.46	....
		Sundry Claims	....	....	....	....	....	....	....	117.25	203.16	....
	From Goldfield generally :—											
	Sundry Parcels treated at :											
		State Battery, Peak Hill	....	....	....	....	....	....	3.05	15.00	*7,171.41	....
		Various Works	....	....	....	....	....	....	....	2,636.00	*7,458.36	24.60
	Reported by Banks and Gold Dealers		....	....	....	....	....	2,858.58	444.91	....	15.88	.14
		Total	....	**6.18**			**.17**	**3,387.79**	**5,377.97**	**783,070.73**	**322,738.34**	**3,794.07**

East Murchison Goldfield.

LAWLERS DISTRICT.

Kathleen Valley	....	Voided Leases	....	....	....	....	....	....	144.85	80,963.66	49,054.32	1.57
		Sundry Claims	....	....	....	....	....	14.37	526.03	5,836.75	2,662.74	893.45
Lawlers	G.M.L.s 1363, 1364 (1366)	Kim Prospecting and Development Syndicate	....	....	....	....	....	....	....	290.00	25.64	....
	1236	Waroonga	....	....	....	....	....	....	....	....	99.40	.50
		Voided Leases	....	....	....	....	....	25.51	692.45	1,622,917.40	575,150.65	14,803.08
		Sundry Claims	....	....	....	....	....	401.71	451.61	17,805.98	9,801.02	275.42

Table I.—*Production of Gold and Silver from all sources, etc.*—continued.

Mining Centre	Number of Lease	Registered Name of Company or Lease	Total for 1966					Total Production				
			Alluvial	Dollied and Specimens	Ore treated	Gold therefrom	Silver	Alluvial	Dollied and Specimens	Ore treated	Gold therefrom	Silver
			Fine ozs.	Fine ozs.	Tons (2,240 lb.)	Fine ozs.	Fine ozs.	Fine ozs.	Fine ozs.	Tons (2,240 lb.)	Fine ozs.	Fine ozs.
EAST MURCHISON GOLDFIELD—continued.												
LAWLERS DISTRICT—continued.												
Sir Samuel	....	Voided Leases	....	....	....	....	....	....	359.03	275,417.55	141,829.52	10,234.80
		Sundry Claims	....	....	....	....	....	57.64	64.96	7,851.00	4,585.10	.02
Wildara Station	1385	Mangilla	....	....	597.00	507.67	5.25	....	....	1,334.00	1,400.84	36.18
	1382, 1383	Rowley's Find Leases	....	....	363.00	107.56	.65	....	....	1,136.00	422.00	6.86
	1388	Tahmoo	....	....	736.00	149.79	....	....	....	736.00	149.79	....
	(1386)	Wedge Extended	....	....	30.00	24.32	1.72	....	....	88.00	56.13	2.15
		Voided Leases	....	....	....	....	....	....	....	1,697.50	607.17	1.00
		Sundry Claims	....	....	278.00	103.49	....	143.23	....	1,275.75	685.83	29.71
	From District generally :—											
	Sundry Parcels treated at :											
		Various Works	....	....	....	....	....	2.12	2.35	1,774.03	*39,822.19	984.03
		P. R. Rumble (L.T.T. 1631H)	....	....	....	*7.38	....	....	....	....	*7.38	....
		Reported by Banks and Gold Dealers	....	....	....	....	....	6,458.93	101.91	.05	10.00	....
		Total	....	....	**2,004.00**	**900.21**	**7.62**	**7,102.51**	**2,343.19**	**2,019,123.67**	**826,369.72**	**27,268.77**
WILUNA DISTRICT.												
Coles	....	Voided Leases	....	....	....	....	....	....	....	2,765.50	1,240.40	....
		Sundry Claims	....	....	....	....	....	....	21.03	3,909.50	1,531.71	1.40
Corboy's Find	....	Voided Leases	....	....	....	....	....	5.24	1.25	14,946.29	11,036.71	5.00
		Sundry Claims	....	....	....	....	....	21.58	....	9,082.35	5,210.79	....
Gum Creek	....	Voided Leases	....	....	....	....	....	20.75	....	1,380.00	595.73	....
		Sundry Claims	....	....	....	....	....	....	1.36	407.25	131.08	....
Mt. Eureka	....	Voided Leases	....	....	....	....	....	....	....	142.25	96.36	....
		Sundry Claims	....	....	....	....	....	....	....	783.75	548.56	....
Mt. Keith....	....	Voided Leases	....	....	....	....	....	....	44.54	20,259.50	13,551.08	....
		Sundry Claims	....	....	....	....	....	4.81	227.29	3,868.50	2,485.06	.99
New England	....	Voided Leases	....	....	....	....	....	5.74	95.70	5,364.25	3,490.87	....
		Sundry Claims	....	....	....	....	....	9.31	5.78	4,534.75	3,111.97	....
Wiluna	....	Voided Leases	....	....	....	....	....	....	574.76	8,777,986.65	1,789,127.12	10,049.13
		Sundry Claims	....	....	....	....	....	105.39	225.82	27,443.15	10,899.38	1.06

		From District generally :—										
		Sundry Parcels treated at :										
		T. J. Jones (L.T.T. 1446H)	....	....	....	....	....	....	....	....	*103.49	20.30
		Various Works	....	....	....	....	....	....	....	776.00	*29,001.12	232.42
		Reported by Banks and Gold Dealers	....	....	....	....	....	63.66	56.58	....	158.54	12.02
		Total	....	....	....	....	....	**236.48**	**1,254.11**	**8,873,649.69**	**1,872,319.97**	**10,322.32**

BLACK RANGE DISTRICT.

Barrambie	G.M.L. 1124B	Barrambie Range	....	....	19.75	7.93	.58	....	....	19.75	7.93	.58
	1117B	Scheelite Leases	....	....	218.50	136.22	8.58	....	....	1,250.00	795.17	19.60
		Voided Leases	....	....	....	....	....	....	22.49	18,558.42	17,584.28	125.80
		Sundry Claims	....	....	....	....	....	5.07	170.20	993.05	1,068.02	216.73
Bellchambers	....	Voided Leases	....	....	....	....	....	....	111.80	4,349.27	3,130.56	....
		Sundry Claims	....	....	....	....	....	....	....	1,182.80	557.95	....
Birrigrin	....	Voided Leases	....	....	....	....	....	....	820.68	12,042.93	15,086.09	....
		Sundry Claims	....	....	....	....	....	....	179.92	2,487.55	1,238.22	....
Curran's Find	....	Voided Leases	....	....	....	....	....	18.24	222.89	7,252.25	3,116.68	....
		Sundry Claims	....	....	....	....	....	....	29.38	2,158.75	827.18	....
Errolls	....	Voided Leases	....	....	....	....	....	14.17	152.29	14,170.50	9,328.92	....
		Sundry Claims	....	....	....	....	....	6.53	399.11	993.75	602.33	.25
Hancocks	....	Voided Leases	....	....	....	....	....	....	6,968.16	33,726.00	36,664.76	55.72
		Sundry Claims	....	....	....	....	....	4.21	142.89	8,608.10	3,228.18	....
Maninga Marley	....	Voided Leases	....	....	....	....	....	....	195.20	60,833.48	48,494.40	22.55
		Sundry Claims	....	....	....	....	....	....	158.16	3,079.65	1,768.16	....
Montagu	....	Voided Leases	....	....	....	....	....	....	100.17	79,550.60	23,444.82	....
		Sundry Claims	....	....	....	....	....	....	71.09	5,041.35	3,171.19	....
Nungarra	....	Voided Leases	....	....	....	....	....	25.94	952.34	9,709.00	3,662.96	.25
		Sundry Claims	....	....	....	....	....	50.27	1,458.98	7,697.40	2,966.37	....
Sandstone	G.M.L. 958B	Lady Mary	....	....	....	....	....	....	383.35	7,165.75	7,119.35	2.35
		Voided Leases	....	....	....	....	....	4.75	4,449.73	696,625.32	448,299.76	11,754.22
		Sundry Claims	....	....	....	....	....	44.95	1,421.07	16,007.95	6,931.08	....
Youanmi	....	Voided Leases	....	....	....	....	....	.36	126.92	731,497.55	273,884.97	10,474.10
		Sundry Claims	....	....	....	....	....	1.07	18.79	6,258.55	1,814.66	....
		From District generally :—										
		Sundry Parcels treated at :										
		State Battery, Sandstone	....	....	....	....	....	....	....	290.50	*23,575.34	61.02
		Various Works	....	....	....	....	....	....	....	144.50	*17,000.81	....
		Reported by Banks and Gold Dealers	....	....	....	....	....	1,495.40	54.36	....	20.38	.15
		Total	....	....	**238.25**	**144.15**	**9.16**	**1,670.96**	**18,609.97**	**1,731,694.72**	**955,390.52**	**22,733.32**

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 1966					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.												
CUE DISTRICT.												
Big Bell	....	Voided Leases	....	....	....	....	....	....	4.49	5,540,872.50	731,131.65	251,816.67
		Sundry Claims	....	....	....	4.07	6.77	.39	6.32	612.00	494.57	13.48
Cuddingwarra	....	Voided Leases	....	....	....	....	....	10.59	132.46	102,115.91	56,152.11	100.71
		Sundry Claims	....	....	....	....	....	18.46	384.38	10,520.39	5,761.20	18.42
Cue	....	Voided Leases	....	....	....	....	....	202.71	911.60	292,424.49	222,335.12	73.03
		Sundry Claims	....	4.74	....	....	.59	252.92	899.44	47,462.99	20,562.99	5.72
Eelya	G.M.L. 2286	Eagle Hawk	....	....	....	....	....	....	....	150.25	25.44	.73
		Voided Leases	....	....	....	....	....	....	8.78	2,477.75	2,228.56	....
		Sundry Claims	....	....	....	....	....	6.20	143.81	2,309.90	1,099.24	1.31
Mindoolah	....	Voided Leases	....	....	....	....	....	3.07	2.54	9,380.28	5,672.31	42.97
		Sundry Claims	....	....	....	....	....	....	29.30	3,309.85	2,347.36	....
Reedy's	G.M.L. 2289	New Rand	....	....	....	....	....	....	....	1,346.75	303.41	16.75
		Voided Leases	....	....	....	....	....	2.82	219.70	730,260.68	240,487.62	20,472.79
		Sundry Claims	....	....	....	....	....	170.71	137.16	7,295.00	2,690.88	1.24
Tuckabianna	G.M.L. 2237	Gidgie	....	....	....	....	....	....	297.73	3,120.15	2,186.15	36.35
		Voided Leases	....	....	....	....	....	649.70	996.22	13,968.23	7,833.32	4.05
		Sundry Claims	....	....	....	....	....	162.21	489.40	5,777.35	2,810.85	1.32
Tuckenarra	....	Voided Leases	....	....	....	....	....	85.37	3,511.10	19,490.00	22,828.99	172.77
		Sundry Claims	....	....	....	....	....	115.23	797.89	10,196.82	10,313.22	.13
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 :											
	State Battery, Cue		....	....	....	....	....	....	....	76.25	*26,818.66	127.53
	M. Hronsky (L.T.T. 1467H)		....	....	....	33.54	32.57	....	....	....	*302.56	660.18
	Various Works		....	....	....	....	....	....	....	8,615.52	*36,008.51	1,232.12
	Reported by Banks and Gold Dealers		10.81	....	....	....	.76	3,454.74	109.87	....	22.62	1.41
		Total	**10.81**	**4.74**	....	**37.61**	**40.69**	**5,135.12**	**9,109.73**	**6,815,391.30**	**1,402,690.86**	**274,799.68**

MEEKATHARRA DISTRICT.

Abbotts	....	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	1,160.05	790.83	1.22
Gabanintha	....	Voided Leases	....	....	....	....	....	11.79	38.14	33,344.60	22,346.06	830.21
		Sundry Claims	....	....	....	....	....	16.78	159.05	5,391.50	3,020.00	3.67
Garden Gully	....	Voided Leases	....	....	....	....	....	26.36	74.91	30,272.07	21,864.74	1,102.59
		Sundry Claims	....	....	....	....	....	....	18.74	3,023.69	1,725.84	.38
Gum Creek	....	Voided Leases	....	....	....	....	....	25.27	91.96	3,893.08	3,819.91	....
		Sundry Claims	....	....	....	....	....	4.37	84.86	735.05	656.05	....
Holden's	....	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 Pool	....	Voided Leases	....	....	....	....	....	....	....	111.58	82.27	....
		Sundry Claims	....	....	....	....	....	....	2.84	233.57	205.38	....
Meekatharra	G.M.L. 2008N	Fortune Hunter	....	....	492.00	32.04	.42	....	....	492.00	32.04	.42
	2000N	Halcyon	....	....	2,290.00	116.04	5.37	....	....	6,544.50	341.35	14.36
	1559N	Ingliston	....	....	....	....	....	....	498.32	3,223.85	1,895.45	.32
	1529N	Prohibition	....	....	1,373.50	94.76	1.27	....	....	11,567.25	2,576.01	12.79
	1529N, etc.	Prior to transfer to present holders	....	....	....	....	....	....	....	54,266.25	9,949.61	11.83
		Voided Leases	....	....	....	....	....	181.39	1,708.02	1,717,901.82	929,410.51	2,475.62
		Sundry Claims	....	79.99	365.01	27.82	3.02	279.84	1,216.41	32,439.46	11,688.62	12.70
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	....	Voided Leases	....	....	....	....	....	....	....	143.00	281.84	15.85
Nannine	....	Voided Leases	....	....	....	....	....	47.31	844.02	129,492.88	76,482.78	167.45
		Sundry Claims	....	....	....	....	....	138.95	1,301.28	6,775.18	4,787.62	4.55
Quinns	....	Voided Leases	....	....	....	....	....	7.30	1,186.50	33,356.91	13,464.37	90.70
		Sundry Claims	....	....	....	....	....	15.07	1,289.65	3,841.67	2,718.33	....
Ruby Well	....	Voided Leases	....	....	....	....	....	....	43.46	7,461.00	4,046.70	....
		Sundry Claims	....	....	....	....	....	1,015.87	409.39	520.25	629.60	....

Table I.—*Production of Gold and Silver from all sources, etc.*—continued.

MURCHISON GOLDFIELD—continued.

MEEKATHARRA DISTRICT—*continued.*

Mining Centre	Number of Lease	Registered Name of Company or Lease	Total for 1966					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.
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	G.M.L. 1853N	Bluebird	....	....	....	....	....	....	....	10,579.50	3,051.28	3.04
		Voided Leases	....	....	....	....	....	19.03	1,972.23	28,175.54	14,609.36	8.68
		Sundry Claims	....	....	....	....	....	61.89	647.51	11,743.67	5,119.66	1.02
	From District generally :—											
	Sundry Parcels treated at :											
		State Battery, Meekatharra	....	....	....	476.68	....	....	....	193.00	*29,374.89	25.13
		F. M. Scott (L.T.T. 1506H)	....	....	....	21.10	....	....	....	49.00	*319.75	38.87
		Various Works	....	....	....	....	....	....	....	3,947.30	*13,962.97	391.20
		Reported by Banks and Gold Dealers	3.54	....	....	....	....	12,314.09	297.96	451.50	97.71	10.55
		Total	**3.54**	**79.99**	**4,520.51**	**768.44**	**10.08**	**14,704.53**	**18,579.13**	**2,321,890.57**	**1,311,236.37**	**5,277.43**

DAY DAWN DISTRICT.

Mining Centre	Number of Lease	Registered Name of Company or Lease	Alluvial (1966)	Dollied and Specimens (1966)	Ore treated (1966)	Gold therefrom (1966)	Silver (1966)	Alluvial (Total)	Dollied and Specimens (Total)	Ore treated (Total)	Gold therefrom (Total)	Silver (Total)
Day Dawn	G.M.L. 573D, etc.	Mountain View Gold No Liability	....	....	....	....	....	....	....	13,832.85	17,445.73	223.74
		Prior to transfer to present holders	....	....	....	....	....	6.12	100.89	13,290.78	33,849.98	....
		Voided Leases	....	....	....	....	....	160.64	826.65	1,922,088.36	1,225,599.75	169,210.44
		Sundry Claims	....	....	....	....	....	96.42	523.56	13,660.51	6,773.85	2.89
Lake Austin	....	Voided Leases	....	....	....	....	....	613.00	3,079.62	36,872.20	51,050.49	....
		Sundry Claims	....	....	....	....	....	104.98	965.49	3,680.94	1,373.06	9.75
Mainland	....	Voided Leases	....	....	....	....	....	.41	3,296.77	7,575.62	25,026.07	....
		Sundry Claims	....	....	....	....	....	17.85	771.56	1,337.95	701.31	....
Pinnacles	G.M.L. 664D	Eclipse	....	....	....	....	....	....	....	282.75	29.73	....
	676D	Eclipse Amalgamated North	....	....	....	....	....	....	....	187.50	17.68	....
	670D	Eclipse North	....	....	....	....	....	....	....	840.00	47.62	....
		Voided Leases	....	....	....	....	....	4.90	1,213.68	18,280.00	9,915.71	....
		Sundry Claims	....	....	....	....	....	62.93	509.50	4,678.17	1,801.29	....

		From District generally :—										
		Sundry Parcels treated at :										
		Various Works	....	....	....	....	....	....	16.61	988.00	1,996.97	.59
		Reported by Banks and Gold Dealers	.44	....	....	....	....	2,224.36	37.47	....	12.57	.01
		Total	**.44**	....	....	....	....	**3,291.61**	**11,341.80**	**2,037,595.63**	**1,375,641.81**	**169,447.42**

MOUNT MAGNET DISTRICT.

Jumbulyer	....	Voided Leases	....	....	....	....	....	....	15.57	1,651.45	655.39	1.17
		Sundry Claims	....	....	....	....	....	20.32	116.27	1,216.70	886.47	....
Lennonville	G.M.L. 1566M	Empress	....	....	....	....	....	....	....	....	9.51	....
	1637M	Long Reef South	....	....	....	....	....	....	....	224.75	230.27	9.69
		Voided Leases	....	....	....	....	....	....	3,226.91	151,752.55	128,851.38	467.92
		Sundry Claims	....	....	101.75	59.84	1.84	26.00	108.82	15,537.27	6,063.32	11.07
Mt. Magnet	1527M, etc.	Eclipse Gold Mine N.L.	....	....	....	147.08	21.94	....	12.20	36,408.00	41,999.09	4,640.42
		Prior to transfer to present holders	....	....	....	....	....	....	....	294.10	170.77	1.34
	1455M	Evening Star	....	....	....	....	....	....	....	1,083.25	124.35	....
	1287M	Havelock	....	....	....	....	....	....	11.05	4,332.50	840.14	....
	1282M	Hill 50 Gold Mine N.L.	....	....	156,859.00	41,201.49	3,318.86	....	....	2,526,843.40	1,187,231.05	56,215.55
		Prior to transfer to present holders	....	....	....	....	....	....	829.41	8,787.65	4,122.61	.21
	1361M	Jupiter	....	....	....	....	....	....	.83	658.05	261.71	....
	1444M	Late Comer	....	....	....	....	....	....	2.53	511.00	391.31	....
	1447M	Morning Star	....	....	....	....	....	....	....	2,135.40	483.54	1.53
	1475M	Morning Star North	....	....	....	....	....	....	....	11.75	8.13	....
	1536M	Pat O'Meara	....	....	....	....	....	....	....	34.00	.68	....
	1505M	Perseverance	....	....	....	....	....	....	....	107.25	11.40	....
	1654M	Susan Jane	....	....	....	....	....	....	....	8.00	13.71	.45
	1588M	Three Boys	....	....	....	....	....	....	11.11	48.00	2.47	1.11
		Voided Leases	....	....	....	....	....	31.08	9,811.54	852,480.56	325,688.19	859.41
		Sundry Claims	....	....	325.25	85.26	5.56	157.95	2,626.24	61,875.92	30,234.64	29.49
Mt. Magnet East	....	Voided Leases	....	....	....	....	....	63.29	764.53	5,522.28	2,811.75	....
		Sundry Claims	....	....	....	....	....	....	37.22	418.25	428.29	....
Moyagee	....	Voided Leases	....	....	....	....	....	....	23.59	12,472.85	18,334.04	757.77
		Sundry Claims	....	....	....	....	....	14.44	176.21	1,550.75	1,752.39	....
Paynesville	....	Voided Leases	....	....	....	....	....	....	1,613.34	449.77	1,116.15	....
		Sundry Claims	....	....	....	....	....	3.36	540.21	882.57	1,372.00	....
Winjangoo	....	Voided Leases	....	....	....	....	....	.99	202.16	366.25	99.08	1.51
		Sundry Claims	....	....	....	....	....	....	223.32	237.53	71.58	....
		From District generally :—										
		Sundry Parcels treated at :										
		State Battery, Boogardie	....	....	....	....	....	....	....	348.26	*35,102.45	15.62
		Primo Sciaresa (L.T.T. 1615H)	....	....	40.00	66.75	7.19	....	....	40.00	*66.75	7.19
		Various Works	....	....	....	....	....	....	....	100.56	*19,309.19	36.75
		Reported by Banks and Gold Dealers	6.31	....	....	....	.63	2,325.01	114.69	8.00	113.15	.89
		Total	**6.31**	....	**157,326.00**	**41,560.42**	**3,356.02**	**2,642.44**	**20,467.75**	**3,688,398.62**	**1,808,856.95**	**63,059.09**

Table I.—*Production of Gold and Silver from all sources, etc.*—continued.

Mining Centre	Number of Lease	Registered Name of Company or Lease	Total for 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.
Yalgoo Goldfield.												
Bilberatha	....	Voided Leases	....	....	....	....	....	1.27	90.94	3,384.50	1,845.05	....
		Sundry Claims	....	....	....	....	....	....	6.64	3,075.05	1,401.56	....
Carlaminda	....	Voided Leases	....	....	....	....	....	1.28	3.39	2 056.57	862.42	3.30
		Sundry Claims	....	....	....	....	....	....	....	1,368.50	600.68	....
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	....	Voided Leases	....	....	....	....	....	8.64	349.71	39,836.51	28,585.68	1,083.01
		Sundry Claims	....	....	....	....	....	463.12	333.98	1,595.10	588.36	.07
Mt. Farmer	....	Voided Leases	....	....	....	....	....	....	....	64.00	40.19	....
		Sundry Claims	....	....	....	....	....	....	....	462.90	145.06	....
Mt. Gibson	....	Voided Leases	....	....	....	....	....	....	6.44	526.50	888.70	....
		Sundry Claims	....	....	....	....	....	3.95	44.72	1,152.60	502.15	1.00
Ninghan	....	Voided Leases	....	....	....	....	....	....	....	10.00	1.41	....
		Sundry Claims	....	....	....	....	....	....	....	324.75	123.28	....
Noongal	....	Voided Leases	....	....	....	....	....	7.88	31.96	11,263.75	5,771.66	4.04
		Sundry Claims	....	....	....	....	....	39.32	310.31	8,506.55	3,590.35	1.16
Nyoundah	....	Voided Leases	....	....	....	....	....	....	217.63	416.00	183.91	....
		Sundry Claims	....	....	....	....	....	....	30.88	1,229.00	240.38	.54
Pinyalling	....	Voided Leases	....	....	....	....	....	....	313.79	2,318.90	1,146.19	....
		Sundry Claims	....	....	....	....	....	3.27	134.09	1,500.00	959.31	....
Retaliation	....	Voided Leases	....	....	....	....	....	....	....	5,089.25	1,872.98	....
		Sundry Claims	....	....	....	....	....	....	....	913.25	321.52	....

Rothsay	....	Voided Leases	....	....	....	....	....	....	24.06	40,680.75	10,777.98	....
		Sundry Claims	....	....	....	....	....	....	.73	6,469.50	2,562.03	....
Wadgingarra	....	Voided Leases	....	....	....	....	....	....	....	691.11	650.63	....
		Sundry Claims	....	....	....	....	....	....	....	2,147.30	596.20	2.65
Warda Warra	....	Voided Leases	....	....	....	....	....	....	....	10,760.50	5,862.04	....
		Sundry Claims	....	....	....	....	....	....	....	1,108.75	508.63	8.53
Warriedar	....	Voided Leases	....	....	....	....	....	....	....	13,661.50	4,607.88	7.30
		Sundry Claims	....	....	....	....	....	....	2.84	8,867.85	1,950.54	4.54
Yalgoo	....	Voided Leases	....	....	....	....	....	....	3.23	6,314.50	9,965.18	....
		Sundry Claims	....	....	....	....	....	....	23.56	2,622.75	1,010.02	....
Yuin	....	Voided Leases	....	....	....	....	....	....	127.12	68,139.50	27,908.57	130.13
		Sundry Claims	....	....	....	....	....	....	4.70	335.50	67.53	....
	From Goldfield generally :—											
	Sundry Parcels treated at :											
	State Battery, Payne's Find		....	....	....	....	....	....	....	156.50	*4,548.42	....
	Various Works		....	....	....	....	....	9.42	....	865.00	*11,084.64	100.91
	Reported by Banks and Gold Dealers		7.00	....	....	....	.65	972.19	59.13	....	48.90	1.54
		Total	7.00	....	....	....	.65	**1,815.77**	**3,224.00**	**443,349.58**	**264,036.39**	**1,523.06**

Mt. Margaret Goldfield.

MOUNT MORGANS DISTRICT.

Australia United	....	Voided Leases	....	....	....	....	....	....	1,911.63	15,913.69	23,305.76	1.76
		Sundry Claims	....	....	....	....	....	....	580.98	1,307.50	2,227.65	....
Eucalyptus	....	Voided Leases	....	....	....	....	....	....	2,878.56	1,603.85	3,251.01	....
		Sundry Claims	....	....	....	....	....	....	591.62	2,160.30	2,011.78	....
Jasper Hill (Irwin Hills)	....	Sundry Claims	....	....	....	....	....	....	....	75.00	8.89	.53
Linden	....	Voided Leases	....	....	....	....	....	7.53	566.97	72,919.81	66,208.35	.68
		Sundry Claims	....	....	140.00	26.24	....	132.11	244.96	19,850.35	13,913.23	2.29
Mt. Margaret	....	Voided Leases	....	....	....	....	....	12.13	1.89	8,900.39	5,291.51	12.55
		Sundry Claims	....	....	....	....	....	25.22	111.18	1,790.10	661.42	....
Mt. Morgans	G.M.L.'S 399F, etc.	Morgans Gold Mines Ltd.	....	....	....	....	....	....	....	5,070.05	13,981.69	....
		Prior to transfer to present holders	....	....	....	....	....	....	16.66	779,578.43	354,225.86	5,552.68
		Voided Leases	....	....	....	....	....	17.95	148.79	61,354.50	34,786.53	77.86
		Sundry Claims	....	....	....	....	....	36.41	398.78	5,104.07	3,396.77	....
Murrin Murrin	....	Voided Leases	....	....	....	....	....	10.43	231.35	136,940.22	104,029.97	29.60
		Sundry Claims	....	....	....	....	....	51.15	560.71	6,887.68	4,785.37	16.19
Redcastle	....	Voided Leases	....	....	....	....	....	4.49	491.33	4,284.95	4,111.85	....
		Sundry Claims	....	....	....	....	....	....	113.84	1,219.57	658.94	....

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 1966					Total Production				
			Alluvial	Dollied and Specimens	Ore treated	Gold therefrom	Silver	Alluvial	Dollied and Specimens	Ore treated	Gold therefrom	Silver
			Fine ozs.	Fine ozs.	Tons (2,240 lb.)	Fine ozs.	Fine ozs.	Fine ozs.	Fine ozs.	Tons (2,240 lb.)	Fine ozs.	Fine ozs.
		MOUNT MARGARET GOLDFIELD—continued.										
		MOUNT MORGANS DISTRICT—*continued.*										
Yundamindera	....	Voided Leases	....	....	....	....	....	....	110.93	84,523.85	52,042.94	36.50
		Sundry Claims	....	....	....	....	....	3.01	271.93	6,674.35	4,789.46	....
		From District generally :—										
		Sundry Parcels treated at :										
		Various Works	....	....	....	....	....	113.08	28.03	1,970.35	*24,226.82	100.06
		Reported by Banks and Gold Dealers	....	....	....	....	....	3,161.36	141.84	10.30	95.75	.68
		Total	....	....	**140.00**	**26.24**	....	**3,574.87**	**9,401.98**	**1,218,139.31**	**718,011.55**	**5,831.33**
		MOUNT MALCOLM DISTRICT.										
Cardinia	....	Voided Leases	....	....	....	....	....	13.87	1,598.15	5,531.74	4,238.57	....
		Sundry Claims	....	....	....	....	....	4.25	121.91	2,007.25	714.85	6.60
Diorite	....	Voided Leases	....	....	....	....	....	....	945.65	38,879.03	35,144.28	33.18
		Sundry Claims	....	....	46.00	62.61	....	11.21	332.13	4,701.85	4,576.63	....
Dodger's Well	....	Voided Leases	....	....	....	....	....	....	57.90	1,373.30	1,936.52	....
		Sundry Claims	....	....	....	....	....	.95	28.32	1,440.25	904.23	....
Lake Darlot	G.M.L. (1851C)	Monte Carlo....	....	....	77.00	5.15	....	....	....	194.00	17.49	...
		Voided Leases	....	....	....	....	....	....	4,482.18	83,605.71	52,977.46	17.02
		Sundry Claims	....	....	42.00	13.87	....	129.92	906.52	12,316.12	6,790.60	45.18
Leonora	G.M.L.'s 1762C, etc.	Sons of Gwalia Ltd.	....	....	....	302.14	8.05	....	....	7,030,740.53	2,581,154.05	188,812.19
		Prior to transfer to present holders	....	....	....	....	....	....	....	109,081.00	55,989.21	8.66
		Voided Leases	....	....	....	....	....	....	2,452.07	179,084.50	93,505.01	110.02
		Sundry Claims	....	....	247.00	117.43	....	37.73	377.26	22,584.45	12,854.48	26.77
Mt. Malcolm	....	Voided Leases	....	....	....	....	....	11.65	47.07	62,656.53	47,563.43	....
		Sundry Claims	....	....	....	....	....	5.75	35.60	4,969.47	2,731.02	1.85
Mertondale	....	Voided Leases	....	....	....	....	....	....	....	89,024.75	60,935.32	1,497.58
		Sundry Claims	....	....	....	....	....	5.42	85.74	3,391.41	2,321.64	.87
Mt. Clifford	1852C	J.B.H.	....	....	93.00	11.92	....	....	....	93.00	11.92	....
		Voided Leases	....	....	....	....	....	....	1,786.51	9,588.96	16,640.81	....
		Sundry Claims	....	....	30.00	1.56	....	53.98	1,860.00	5,632.70	3,499.20	.24

Pig Well	....	Voided Leases	....	....	....	....	....	....	....	13,587.32	14,676.58	63.68
		Sundry Claims	....	....	....	....	....	....	34.61	2,896.65	1,225.46	....
Randwick	....	Voided Leases	....	....	....	....	....	....	246.76	10,912.65	9,736.57	....
		Sundry Claims	....	....	....	....	....	66.57	164.02	2,551.64	1,320.66	....
Webster's Find	....	Voided Leases	....	....	....	....	....	30.30	....	22,167.50	14,377.65	....
		Sundry Claims	....	....	....	....	....	36.84	695.68	2,356.15	1,530.56	....
Wilson's Creek	....	Voided Leases	....	....	....	....	....	....	....	333.50	168.27	....
		Sundry Claims	....	....	....	....	....	.70	4.24	316.00	261.12	....
Wilson's Patch	....	Voided Leases	....	....	....	....	....	....	99.38	28,863.35	13,050.19	1.05
		Sundry Claims	....	....	....	....	....	4.68	54.46	1,712.16	1,436.00	1.12
	From District generally :—											
	Sundry Parcels treated at :											
	State Battery. Lake Darlot		....	....	....	125.64	....	....	....	18.00	*2,640.41	4.98
	P. Sceghi (L.T.T. 1622H)....		....	....	98.00	42.58	....	....	....	98.00	*42.58	....
	Various Works		....	....	....	....	....	....	....	809.50	*25,301.30	158.35
	Reported by Banks and Gold Dealers		....	....	.50	1.77	....	3,653.16	252.83	47.00	59.57	.67
		Total	....	....	**633.50**	**688.27**	**8.05**	**4,066.98**	**16,668.99**	**7,753,565.97**	**3,070,333.64**	**190,790.01**

MOUNT MARGARET DISTRICT.

Burtville	G.M.L. 2567T	Boomerang	....	....	....	....	....	....	....	578.00	34.08	3.67
		Voided Leases	....	....	....	....	....	4.89	419.10	74,268.45	122,454.22	948.27
		Sundry Claims	....	....	....	....	....	2.65	208.27	8,677.66	5,673.60	....
Duketon	....	Voided Leases	....	....	....	....	....	5.35	3,216.10	31,889.42	22,542.63	....
		Sundry Claims	....	....	....	....	....	85.07	528.26	2,442.65	2,196.49	29.76
Eagle's Nest	....	Voided Leases	....	....	....	....	....	....	145.34	534.50	1,238.22	....
		Sundry Claims	....	....	....	....	....	24.07	487.05	1,046.35	360.11	....
Erlistoun	....	Voided Leases	....	....	....	....	....	10.07	393.41	156,731.00	101,641.56	4,327.81
		Sundry Claims	....	....	....	....	....	1,181.65	165.05	5,716.59	3,888.89	....
Euro	....	Voided Leases	....	....	....	....	....	....	65.14	91,821.50	37,678.25	....
		Sundry Claims	....	....	....	....	....	4.87	73.04	1,507.00	835.30	....
Laverton	....	Voided Leases	....	....	....	....	....	28.59	2,028.85	2,131,121.12	820,120.06	56,945.78
		Sundry Claims	....	....	....	....	....	215.58	1,492.90	17,552.50	9,256.80	....
Mt. Barnicoat	....	Voided Leases	....	....	....	....	....	....	23.08	2,370.00	2,251.99	....
		Sundry Claims	....	....	....	....	....	....	.68	1,309.75	1,087.77	....
Mt. Shenton	....	Voided Leases	....	....	....	....	....	....	....	15.00	26.65	....
		Sundry Claims	....	....	....	....	....	....	....	279.25	209.67	....
	From District generally :—											
	Sundry Parcels treated at :											
	State Battery, Laverton		....	....	....	....	....	....	....	97.50	*19,327.97	561.11
	Various Works		....	....	....	....	....	....	....	215.00	*23,190.12	3,374.30
	Reported by Banks and Gold Dealers		....	....	....	....	....	2,584.74	108.08	....	29.18	....
		Total	....	....	....	....	....	**4,147.53**	**9,354.35**	**2,528,173.24**	**1,174,043.56**	**61,190.70**

Table I.—*Production of Gold and Silver from all sources, etc.*—continued.

Mining Centre	Number of Lease	Registered Name of Company or Lease	Total for 1966					Total Production				
			Alluvial	Dollied and Specimens	Ore treated	Gold therefrom	Silver	Alluvial	Dollied and Specimens	Ore treated	Gold therefrom	Silver
			Fine ozs.	Fine ozs.	Tons (2,240 lb.)	Fine ozs.	Fine ozs.	Fine ozs.	Fine ozs.	Tons (2,240 lb.)	Fine ozs.	Fine ozs.

North Coolgardie Goldfield.

MENZIES DISTRICT.

Mining Centre	Number of Lease	Registered Name of Company or Lease	Alluvial (1966)	Dollied and Specimens (1966)	Ore treated (1966)	Gold therefrom (1966)	Silver (1966)	Alluvial (Total)	Dollied and Specimens (Total)	Ore treated (Total)	Gold therefrom (Total)	Silver (Total)
Comet Vale	G.M.L. 5766Z	Coonega Extended	....	....	13.00	1.48	....	....	....	113.25	37.03	....
		Voided Leases	....	....	....	....	....	....	419.74	267,668.97	193,272.82	5,355.33
		Sundry Claims	....	....	94.00	7.58	....	....	40.19	2,330.96	1,183.72	....
Goongarrie	5740Z	Gull's Blow	....	....	....	....	....	1.90	167.25	374.75	265.78	....
		Voided Leases	....	....	....	....	....	.94	1,385.26	29,897.79	18,124.83	....
		Sundry Claims	....	....	54.85	43.33	....	46.46	2,144.42	3,035.45	3,445.65	....
Menzies	5793Z	Black Swan	....	....	367.00	30.96	....	....	....	1,788.25	134.88	....
	5794Z	Callie	....	....	....	....	....	....	....	315.50	85.32	....
	5799Z	First Hit	....	....	50.50	33.62	....	....	....	50.50	33.62	....
	5542Z	Good Block Lease	....	....	598.50	20.69	....	....	7.32	4,936.80	3,146.93	....
	5780Z	Good Enough	....	....	....	....	....	....	....	3,864.70	1,041.58	1.54
	5520Z	Mignonette	....	....	....	....	....	....	....	808.50	404.43	....
		Voided Leases	....	....	....	....	....	45.42	1,271.30	1,015,814.33	785,944.73	20,296.55
		Sundry Claims	....	....	371.30	63.13	....	56.87	624.33	42,479.69	26,521.72	813.76
Mt. Ida	5701Z, etc.	Moonlight Wiluna Gold Mines Ltd.	....	....	24,910.00	9,697.24	1,422.79	....	40.77	449,072.86	229,398.10	7,089.14
		Prior to transfer to present holders	....	....	....	....	....	....	....	31,833.25	16,021.98	891.37
		Voided Leases	....	....	....	....	....	....	92.21	68,748.92	72,681.44	106.63
		Sundry Claims	....	....	77.70	3.74	....	48.14	436.08	16,195.11	8,284.32	.12
Twin Hills	....	Voided Leases	....	....	....	....	....	....	....	582.30	574.93	....
		Sundry Claims	....	....	....	....	....	....	....	97.80	86.69	....
From District generally :—												
Sundry Parcels treated at :												
State Battery, Mt. Ida			....	....	....	....	....	....	....	1,866.25	*7,556.16	2.04
State Battery, Menzies			....	....	....	....	....	....	....	20.00	*3,810.10	1,032.66
Various Works			....	....	....	....	....	....	....	3,216.05	*58,804.12	3,062.11
Reported by Banks and Gold Dealers			....	....	....	....	....	1,496.96	403.22	100.00	48.49	....
		Total	....	....	**26,536.85**	**9,901.77**	**1,422.79**	**1,696.69**	**7,032.09**	**1,945,211.98**	**1,430,909.37**	**38,651.25**

ULARRING DISTRICT.

Mining Centre	Number of Lease	Registered Name of Company or Lease	Alluvial (1966)	Dollied and Specimens (1966)	Ore treated (1966)	Gold therefrom (1966)	Silver (1966)	Alluvial (Total)	Dollied and Specimens (Total)	Ore treated (Total)	Gold therefrom (Total)	Silver (Total)
Davyhurst	....	Voided Leases	....	....	....	....	....	2.93	152.64	304,354.62	195,751.92	21,336.15
		Sundry Claims	....	....	52.00	2.39	....	....	208.48	14,212.19	5,789.68	....

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 1966					Total Production				
			Alluvial	Dollied and Specimens	Ore treated	Gold therefrom	Silver	Alluvial	Dollied and Specimens	Ore treated	Gold therefrom	Silver
			Fine ozs.	Fine ozs.	Tons (2,240 lb.)	Fine ozs.	Fine ozs.	Fine ozs.	Fine ozs.	Tons (2,240 lb.)	Fine ozs.	Fine ozs.
		YERILLA DISTRICT										
Edjudina	....	Voided Leases	....	....	....	....	....	....	18.44	35,523.70	43,374.79	37.79
		Sundry Claims	....	....	....	....	....	....	28.52	6,967.58	4,829.77	.69
Patricia	....	Voided Leases	....	....	....	....	....	....	....	4,158.50	5,396.40	25.40
		Sundry Claims	....	....	....	....	....	....	....	47.00	20.78	....
Pinjin	....	Voided Leases	....	....	....	....	....	....	48.34	17,463.30	10,742.77	....
		Sundry Claims	....	....	....	....	....	....	154.86	5,642.59	3,475.75	....
Yarri	G.M.L. (1347R)	Dawn	....	....	29.00	1.80	....	....	....	190.50	27.63	....
	1320R	Margaret	....	....	....	....	....	....	....	4,683.00	1,327.51	.32
	1126R, etc.	Porphyry (1939) Gold Mines N.L.	....	....	....	....	....	....	....	66,939.00	9,893.51	261.95
		Prior to transfer to present holders	....	....	....	....	....	....	....	30,344.50	5,448.82	507.51
	1339R	Yilgangie	....	....	7.00	6.59	....	....	....	929.00	399.75	9.42
		Voided Leases	....	....	....	....	....	6.30	87.08	45,573.75	21,404.41	2.00
		Sundry Claims	....	....	28.00	5.08	....	.87	5.93	18,306.05	6,381.06	1.40
Yerilla	....	Voided Leases	....	....	....	....	....	....	3,107.25	16,481.43	12,925.74	13.93
		Sundry Claims	....	....	....	....	....	19.30	97.63	2,752.83	1,590.03	....
Yilgangie	1176R, etc.	Western Mining Corporation	....	....	....	....	....	....	....	32,899.50	30,534.87	4,471.98
		Prior to transfer to present holders	....	....	....	....	....	....	.85	1,244.75	1,830.28	....
Yilgangie	....	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		....	....	....	46.83	1.48	....	....	276.50	*9,107.01	13.13
	Various Works		....	....	....	....	....	2.17	....	642.25	*6,092.76	....
	Reported by Banks and Gold Dealers		.27	....	....	....	....	1,162.23	160.08	....	28.80	.09
		Total	**.27**	....	**64.00**	**60.30**	**1.48**	**1,312.54**	**3,817.12**	**296,879.78**	**178,404.08**	**5,346.24**

Broad Arrow Goldfield.

Mining Centre	Number of Lease	Registered Name of Company or Lease	Alluvial (1966)	Dollied and Specimens (1966)	Ore treated (1966)	Gold therefrom (1966)	Silver (1966)	Alluvial (Total)	Dollied and Specimens (Total)	Ore treated (Total)	Gold therefrom (Total)	Silver (Total)
Bardoc	G.M.L. 2333W	Patience	....	....	113.00	19.43	....	....	....	113.00	19.43	....
	2325W	Pride	....	....	91.50	36.48	....	....	....	228.00	369.69	....
		Voided Leases	....	....	....	....	....	....	2,335.41	85,426.84	55,705.22	203.60
		Sundry Claims	....	....	263.65	7.15	....	54.95	1,218.09	18,285.68	8,544.92	....
Black Flag	2229W	Bellevue	....	....	73.75	15.65	....	....	212.68	4,210.23	3,272.12	9.92
	2320W	Bellevue South	....	....	174.50	356.47	15.57	....	....	306.50	581.12	24.26
		Voided Leases	....	....	....	....	....	27.81	405.90	48,428.54	28,212.48	2.04
		Sundry Claims	....	....	....	....	....	712.92	251.59	8,399.66	5,027.14	....

Morleys	G.M.L. 1094U	First Hit	....	....	93.50	110.58	....	....	82.48	5,471.00	7,424.06	11.89
	1168U	Hazel Dawn	....	....	....	....	....	....	....	51.25	104.97	....
	1081U	Mabel Gertrude	....	....	13.00	24.04	....	....	17.19	1,824.25	2,138.12	....
	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	....	....	411.00	49.35	....	....	....	1,001.50	153.77	....
		Voided Leases	....	....	....	....	....	....	274.09	136,211.82	117,741.26	530.82
		Sundry Claims	....	....	393.25	27.08	....	10.82	296.42	11,619.89	9,942.49	1.14
Mulwarrie	1153U	Four Mile	....	....	....	....	....	....	....	115.50	778.02	11.32
	1113U	Oakley	....	....	206.00	155.70	....	....	....	5,228.00	8,384.18	333.95
		Voided Leases	....	....	....	....	....	....	165.29	19,480.68	26,369.21	38.47
		Sundry Claims	....	....	....	....	....	.80	282.29	3,106.33	2,722.13	....
Ularring	....	Voided Leases	....	....	....	....	....	....	563.34	9,771.60	13,907.76	....
		Sundry Claims	....	....	....	....	....	....	....	671.50	309.48	....
From District generally :—												
Sundry Parcels treated at :												
Various Works			....	....	....	....	....	....	15.82	1,521.32	*33,793.18	12.68
Reported by Banks and Gold Dealers			....	....	....	....	....	112.95	424.28	100.00	106.72	.01
		Total	....	....	**1,168.75**	**369.14**	....	**129.66**	**7,298.59**	**536,986.45**	**446,956.29**	**22,286.97**

NIAGARA DISTRICT.

Desdemona	....	Voided Leases	....	....	....	....	....	....	7.12	9,809.00	7,555.81	12.04
		Sundry Claims	....	....	....	....	....	....	10.35	2,225.45	892.48	....
Kookynie	G.M.L. 911G	Cosmopolitan South	....	....	....	....	....	....	....	2,650.00	1,384.37	....
		Voided Leases	....	....	....	....	....	3.35	347.30	759,883.21	402,777.41	5,404.72
		Sundry Claims	....	....	11.50	4.13	....	60.92	106.60	9,525.30	6,977.38	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	8,092.58	4,128.44	....
From District generally :—												
Sundry Parcels treated at :												
Various Works			....	....	....	....	....	....	....	1,220.50	*20,884.22	120.98
Reported by Banks and Gold Dealers			....	....	....	....	....	1,593.51	823.66	....	63.53	....
		Total	....	....	**11.50**	**4.13**	....	**1,718.48**	**1,821.77**	**944,448.02**	**528,582.27**	**5,716.17**

Broad Arrow	....	Voided Leases	....	....	....	....	....	70.32	10,453.81	155,928.94	120,097.62	20.23
		Sundry Claims	.84	....	1,469.00	87.73	....	1,008.56	3,054.58	38,602.40	17,516.70	1.06
Canegrass	....	Voided Leases	....	....	....	....	....	....	27.77	669.82	460.72	....
		Sundry Claims	....	....	....	....	....	....	227.55	717.45	505.06	....
Carnage	....	Voided Leases	....	....	....	....	....	176.04	659.31	2,402.00	2,170.67	....
		Sundry Claims	....	....	....	....	....	....	6.61	2,340.33	921.90	....
Cashmans	....	Voided Leases	....	....	....	....	....	67.51	813.76	8,172.15	7,090.91	....
		Sundry Claims	....	....	62.75	311.17	....	....	40.31	1,300.62	679.45	.05
Christmas Reef	....	Voided Leases	....	....	....	....	....	....	55.49	5,891.12	7,636.49	7.56
		Sundry Claims	....	....	50.75	6.41	....	....	441.85	3,431.39	3,257.97	....
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	....	....	36.50	34.88	....	....	....	951.00	808.43	5.41
	2278W	Prince of Wales	....	....	320.00	188.36	....	....	....	1,531.00	2,186.61	56.51
	2277W, 2278W	(Ora Banda Amalgamated Mines N.L.)	....	....	.05	.55	....	....	1.53	973.60	1,155.62	.18
		Voided Leases	....	....	....	....	....	....	274.13	204,083.59	80,144.60	175.00
		Sundry Claims	....	....	49.25	13.87	....	....	356.66	7,690.87	3,355.40	4.28
Ora Banda	G.M.L. 2270W, 2290W	Gimlet South Leases	....	....	4,077.50	217.18	....	....	....	48,052.50	5,781.57	164.62
	2331W	Renown	....	....	19.50	109.81	5.45	....	....	19.50	109.81	5.45
	2300W	Sleeping Beauty	....	....	410.25	69.55	....	....	....	3,660.25	1,061.98	1.14
	2315W	Victorious	....	....	203.50	12.01	....	....	....	1,146.00	49.04	....
		Voided Leases	....	....	....	....	....	....	846.13	423,677.27	151,230.99	1,685.77
		Sundry Claims	....	....	650.50	73.67	....	....	467.18	16,855.30	5,034.85	....
Paddington	2339W	Paddington Consuls South	....	....	63.00	46.10	....	....	....	63.00	46.10	....
	2298W	Rona Lucille	....	....	248.15	114.63	....	....	....	640.75	517.55	17.97
		Voided Leases	....	....	....	....	....	5,566.30	463.31	196,486.56	86,485.99	32.15
		Sundry Claims	....	....	207.00	23.18	....	1,714.16	291.43	17,851.93	9,364.83	....
Riche's Find	2306W	Cave Hill	....	....	....	....	....	....	238.15	75.85	154.93	....
		Voided Leases	....	....	....	....	....	....	21.64	7,643.09	6,095.69	71.36
		Sundry Claims	....	....	....	....	....	....	549.09	2,112.50	2,526.77	.13
Siberia	....	Voided Leases	....	....	....	....	....	1.07	2,649.28	28,995.47	31,776.06	....
		Sundry Claims	....	....	50.00	2.16	....	289.06	1,261.72	21,374.59	12,895.59	....
Smithfield	2296W	Timewell	....	....	....	....	....	....	12.51	53.78	63.12	....
		Voided Leases	....	....	....	....	....	....	19.19	11,717.71	2,068.58	....
		Sundry Claims	....	....	....	....	....	....	124.29	3,969.59	1,400.01	.11
		From Goldfield generally :—										
		Sundry Parcels treated at :										
		State Battery, Ora Banda	....	....	....	524.68	1.37	....	....	128.05	*28,079.88	76.75
		Various Works	....	....	....	....	....	2,275.66	1.24	17,048.27	*53,850.36	3,105.75
		Reported by Banks and Gold Dealers	2.46	....	....	....	....	10,031.46	166.91	61.68	95.83	.15
		Total	**3.30**	....	**8,634.10**	**2,271.12**	**22.39**	**21,995.82**	**28,005.48**	**1,411,648.89**	**752,197.12**	**5,671.45**

Table I.—*Production of Gold and Silver from all sources, etc.*—continued

North-East Coolgardie Goldfield.

Mining Centre	Number of Lease	Registered Name of Company or Lease	Total for 1966					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.
		KANOWNA DISTRICT.										
Gindalbie	....	Voided Leases	....	....	....	....	....	....	1,151.99	46,449.78	41,928.37	38.41
		Sundry Claims	....	....	10.50	2.45	....	....	716.52	5,871.27	3,312.48	.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	1,675.00	1,052.74	.16
Kanowna	G.M.L. 1585X	New Kanowna	....	....	11.00	25.58	....	....	....	22.00	94.16	....
	1572X	Kanowna Red Hill	....	108.94	90.00	197.40	....	....	111.32	4,113.75	1,611.73	9.07
		Voided Leases	....	....	....	....	....	24.94	4,516.76	685,625.60	380,504.87	2,482.24
		Sundry Claims	....	....	296.75	111.88	....	125.32	2,169.07	28,801.82	12,292.89	1.71
Mulgarrie	....	Voided Leases	....	....	....	....	....	....	1,216.63	6,902.26	4,197.98	....
		Sundry Claims	....	....	....	....	....	....	16.78	1,290.00	646.60	....
Six Mile	....	Voided Leases	....	....	....	....	....	....	1,603.72	559.00	767.72	....
		Sundry Claims	....	....	....	....	....	....	56.51	771.75	232.66	....
From District generally :— Sundry Parcels treated at :												
		Various Works	....	....	....	....	....	330.42	867.52	158,935.05	*153,209.41	....
		Reported by Banks and Gold Dealers	2.75	....	....	....	....	106,040.63	40.42	.50	109.73	....
		Total	**2.75**	**108.94**	**408.25**	**337.31**	....	**106,546.01**	**13,635.61**	**1,010,727.81**	**628,017.50**	**3,049.28**
		KURNALPI DISTRICT.										
Jubilee	....	Voided Leases	....	....	....	....	....	....	145.13	2,122.50	1,465.16	....
		Sundry Claims	....	....	....	....	....	25.57	13.52	1,264.00	527.32	....
Karonie	G.M.L. (463K)	Rowe's Find	....	....	18.50	4.80	....	....	....	18.50	4.80	....
		Voided Leases	....	....	....	....	....	....	....	384.75	164.96	....
		Sundry Claims	....	....	50.50	17.17	....	....	....	183.00	77.97	....
Kurnalpi	....	Voided Leases	....	....	....	....	....	371.18	3,166.80	4,130.76	4,022.13	6.27
		Sundry Claims	....	....	6.00	9.20	....	324.12	727.39	4,624.86	2,383.26	....
Mulgabbie....	457K	Mulgabbie Lucknow	....	....	....	....	....	....	....	70.00	6.72	....
		Voided Leases	....	....	....	....	....	....	1,402.66	226.75	7,845.87	4.95
		Sundry Claims	....	....	15.00	6.76	....	8.06	2,772.71	1,346.45	2,273.88	....

		From District generally :—										
		Sundry Parcels treated at :										
		Various Works	....	....	....	....	....	....	....	101.50	*388.63	....
		Reported by Banks and Gold Dealers	....	....	....	....	....	12,108.34	70.70	....	2.35	1.49
		Total	....	....	**90.00**	**37.93**	....	**12,837.27**	**8,298.91**	**14,473.07**	**19,163.05**	**12.71**

East Coolgardie Goldfield.

EAST COOLGARDIE DISTRICT.

Binduli	....	Voided Leases	....	....	....	....	....	....	....	1,904.60	495.36	....
		Sundry Claims	....	....	17.25	3.81	....	....	13.01	6,110.12	1,764.54	.34
Boorara	....	Voided Leases	....	....	....	....	....	....	459.07	309,467.82	172,861.95	411.37
		Sundry Claims	....	....	87.00	36.91	1.69	.49	145.56	4,359.09	1,619.47	1.92
Boulder	G.M.L. 6145E	Boomerang	....	....	....	....	....	....	....	77.00	8.00	....
	5531E	Cassidy's Hill	....	....	....	....	....	....	....	1,508.50	134.31	....
	5964E	Croesus Extended	....	....	....	....	....	....	....	192.75	16.57	....
	5159E, etc.	Gold Mines of Kalgoorlie (Aust.) Ltd.	....	....	468,779.00	107,789.04	39,171.08	....	....	5,038,036.00	1,294,141.73	338,284.92
		Prior to transfer to present holders	....	....	....	....	....	....	849.95	15,916,923.07	6,416,710.17	819,123.27
	5695E–5780E, 6254E	Great Boulder Proprietary Gold Mines Ltd.	....	....	360,417.00	83,128.62	49,462.31	....	1.53	16,200,466.97	6,927,060.07	1,800,363.34
	5478E, etc.	Lake View & Star Ltd.	....	....	644,625.00	148,130.00	18,114.24	....	....	19,831,302.30	5,649,764.77	630,712.10
		Prior to transfer to present holders	....	....	....	....	....	....	8.49	15,792,500.38	9,149,223.80	1,348,055.82
	5413E, etc.	North Kalgurli (1912) Ltd.	....	....	364,140.00	70,108.30	36,126.58	....	127.55	7,940,391.24	2,051,004.41	564,335.99
	5405E, etc.	North Kalgurli (1912) Ltd. (Croesus Pty. Group)	....	....	....	....	....	....	51.20	90,159.00	19,261.22	....
		Prior to transfer to present holders	....	....	....	....	....	43.99	....	4,018,629.01	2,815,959.95	97,625.03
		Voided Leases	....	....	....	....	....	129.24	12,023.37	1,822,556.06	761,933.46	24,046.96
		Sundry Claims	....	....	....	....	....	24.58	212.32	11,649.99	4,300.62	....
Cutters Luck	....	Voided Leases	....	....	....	....	....	45.87	133.58	74.50	239.19	....
		Sundry Claims	....	....	....	....	....	8.11	501.65	922.90	384.71	....
Feysville	....	Voided Leases	....	....	....	....	....	....	110.93	863.30	425.16	....
		Sundry Claims	....	....	53.00	7.62	....	....	199.00	1,427.75	670.37	....
Hampton Plains	P.P.L. 277, Loc. 50	Joyce & Africh	....	....	298.75	42.88	....	....	....	12,163.50	1,047.77	1.48
	P.P.L. 476, Loc. 48	Ivy Rose	....	....	....	....	....	....	7.75	175.80	307.37	.72
	P.P.L. 488, Loc. 48	L. Lethlean	....	....	....	....	....	....	....	4.50	9.95	....
	P.P.L. 175A, Loc. 48	S. Shackleton	....	....	46.25	6.46	....	....	....	265.50	44.80	.27
	P.P.L. 280, Loc. 48	W. J. White	....	....	59.75	6.19	....	....	....	352.75	58.58	....
	Lease 1, Loc. 50	Western Mining Corporation Ltd.	....	....	....	....	....	....	....	4,151.00	361.62	86.37
		Cancelled Leases	....	....	....	....	....	4,585.24	258.74	374,334.92	98,839.10	5,906.27
		Sundry Claims	....	....	....	....	....	2.68	110.46	46,838.41	8,650.24	.13

Table I.—*Production of Gold and Silver from all sources, etc.*—continued.

Mining Centre	Number of Lease	Registered Name of Company or Lease	Total for 1966					Total Production				
			Alluvial	Dollied and Specimens	Ore treated	Gold therefrom	Silver	Alluvial	Dollied and Specimens	Ore treated	Gold therefrom	Silver
			Fine ozs.	Fine ozs.	Tons (2,240 lb.)	Fine ozs.	Fine ozs.	Fine ozs.	Fine ozs.	Tons (2,240 lb.)	Fine ozs.	Fine ozs.
		EAST COOLGARDIE GOLDFIELD—continued.										
		EAST COOLGARDIE DISTRICT—*continued*										
Kalgoorlie....	G.M.L. 6562E	Bretvic	....	....	....	....	....	....	....	326.50	26.09	....
	6503E	Coronation	....	....	....	....	....	....	....	20.50	2.52	....
	5510E	Golden Dream	....	....	....	....	....	....	....	254.75	26.24	....
		Prior to transfer to present holders	....	....	....	....	....	....	....	530.74	149.77	....
	6636E	Golden Cross	....	....	....	....	....	....	....	71.00	4.11	....
	6620E	Golden Goose	....	....	....	....	....	....	....	60.50	2.85	....
	6537E	Golden Key	....	....	16.50	31.32	....	....	....	16.50	31.32	....
	6630E	Golden Star	....	....	....	....	....	....	....	1,296.00	44.23	....
	G.M.L. 6502E	Gold Mines of Kalgoorlie (Aust.) Ltd. (Hannans North Mine)	....	....	....	....	....	....	....	10,334.75	2,235.53	7.56
		Prior to transfer to present holders	....	....	....	....	....	....	....	256.00	65.07	4.28
	6591E	Gold Mines of Kalgoorlie (Aust.) Ltd. (Kalgoorlie Star Mine)	....	....	....	....	....	....	....	10,712.00	831.89	....
		Prior to transfer to present holders	....	....	....	....	....	....	....	51.50	18.22	.57
	6563E, etc.	Gold Mines of Kalgoorlie (Aust.) Ltd. (Mt. Charlotte Mine)	....	....	381,174.00	50,346.79	....	....	....	779,198.00	105,173.84	....
		Prior to transfer to present holders	....	....	....	....	....	....	5.72	85,723.60	18,167.21	171.56
	6589E	Grays Central	....	....	78.50	77.13	2.97	....	....	954.25	276.91	2.97
	6091E	Lesanben	....	....	41.05	50.12	....	....	193.96	1,314.10	873.49	3.88
	6485E	Maritana Hill	....	....	....	....	....	....	....	3,331.25	405.43	....
	6535E	Mary A.	....	....	....	....	....	....	....	5,915.00	552.61	.14
	6615E	Middle Hannans	....	....	62.50	4.81	....	....	....	273.25	17.00	....
	6639E	Old Hinchcliffe	....	....	130.50	30.83	....	....	....	485.50	82.79	....
	6642E	Olive K	....	....	....	....	....	....	....	31.75	8.42	....
	5852E, (6024E)	Pedestal Leases	....	....	....	....	....	....	....	1,828.50	490.37	....
	5852E	Pedestal	....	....	62.00	3.44	....	....	....	1,763.50	465.36	....
		Voided Leases	....	....	....	....	....	242.48	10,802.28	1,474,676.27	582,592.35	45,975.97
		Sundry Claims	....	....	39.25	3.69	....	232.41	1,124.98	63,885.12	23,480.77	.20
Wombola	5689E, etc.	Haoma Leases	....	....	100.00	25.80	....	....	....	6,910.50	7,803.93	1,011.58
		Prior to transfer to present holders	....	....	....	....	....	....	.25	60,201.00	57,932.14	827.18
	5497E, 5500E	Daisy Leases	....	....	184.00	151.20	....	....	....	21,965.45	19,898.68	884.76
	5497E	Daisy	....	....	....	....	....	....	....	6,282.25	5,031.93	....
	5500E	Happy-go-lucky	....	....	....	....	....	....	....	2,075.25	1,675.85	....
	6635E	Hodad	....	....	101.50	54.10	2.30	....	....	2,965.50	413.05	51.81
	6487E	Leslie	....	....	22.25	15.67	.68	....	....	404.50	370.80	1.17
	6597E	Leslie North	....	....	....	....	....	....	....	810.00	68.40	13.41
	6614E	Logan's Gold Mine	....	....	399.75	58.95	....	....	....	1,136.50	190.40	1.25
	5798E	Maranoa	....	....	....	....	....	....	....	563.00	142.62	5.65
		Prior to transfer to present holders	....	....	....	....	....	....	32.17	3,183.50	1,633.27	....
	6533E	Rosemary	....	....	498.75	335.75	2.08	....	....	10,312.85	10,011.86	123.86
		Voided Leases	....	....	....	....	....	3.80	2,498.57	44,374.34	49,768.87	1.21
		Sundry Claims	....	....	28.00	6.32	....	....	711.10	26,141.43	14,595.18	.20

		From District generally :—										
		Sundry Parcels treated at :										
		State Battery, Kalgoorlie	....	....	....	*535.85	40.33	....	....	390.70	*39,062.10	498.50
		Sundry Claims	....	....	....	....	....	11,014.57	465.61	5,440.46	2,541.10	....
		Linnett & Hawkins (T.A. 75E and 76E)	....	....	....	*64.75	41.26		....	....	*64.75	41.26
		Various Works	....	....	....	....	....	384.36	64.70	41,135.02	*620,788.05	368,306.66
		Reported by Banks and Gold Dealers	4.32	1.30	....	59.14	....	17,015.22	10,074.62	430.68	7,639.49	....
		Total	**4.32**	**1.30**	**2,221,461.55**	**461,115.49**	**142,965.52**	**33,733.04**	**41,188.12**	**90,105,842.49**	**36,952,966.12**	**6,046,891.93**

BULONG DISTRICT.

Balagundi	....	Voided Leases	....	....	....	....	....	....	2,408.98	1,115.93	1,488.91	12.92
		Sundry Claims	....	....	....	....	....	3.51	295.72	806.01	505.93	....
Bulong	G.M.L. 1311Y	Blue Quartz	....	....	....	....	....	....	....	2,031.25	701.61	....
	1342Y	Rocket	....	....	65.00	123.20	....	....	....	93.75	148.26	....
		Voided Leases	....	....	....	....	....	107.54	8,526.12	108,979.05	85,871.31	....
		Sundry Claims	....	....	89.00	19.99	.32	1,655.86	1,611.58	18,446.23	18,121.36	.32
Hampton Plains	....	Voided Leases	....	....	....	....	....	19.45	2.87	1,521.74	611.25	....
Majestic	....	Voided Leases	....	....	....	....	....	....	63.91	1,021.95	386.97	....
		Sundry Claims	....	....	....	....	....	42.88	154.58	1,958.08	973.48	....
Moreland's Find	....	Sundry Claims	....	....	....	....	....	....	.13	308.75	81.84	....
Mt. Monger	....	Voided Leases	....	....	....	....	....	....	2,771.39	1,437.85	1,256.10	....
		Sundry Claims	....	....	....	....	....	215.60	....	379.05	308.48	....
Randalls	....	Voided Leases	....	....	....	....	....	....	60.04	33,180.35	11,100.46	....
		Sundry Claims	....	....	....	....	....	20.70	9.79	4,842.56	1,216.07	....
Taurus	....	Voided Leases	....	....	....	....	....	2.06	3.70	1,765.10	909.84	....
		Sundry Claims	....	....	....	....	....	112.69	51.88	2,694.85	1,060.86	....
Trans Find	....	Voided Leases	....	....	....	....	....	....	....	1,098.42	876.22	....
		Sundry Claims	....	....	....	....	....	....	5.93	728.25	315.06	....
		From District generally :—										
		Sundry Parcels treated at :										
		Various Works	....	....	....	....	....	....	....	6,102.15	*7,154.95	86.52
		Reported by Banks and Gold Dealers			....	....	....	25,225.22	70.15	.01	28.44	....
		Total	....	....	**154.00**	**143.19**	**.32**	**27,405.51**	**16,036.77**	**188,511.33**	**133,117.40**	**99.76**

Coolgardie Goldfield.

COOLGARDIE DISTRICT

Bonnievale	G.M.L. 5986	Jenny Wren	....	....	....	....	....	....	....	401.00	236.05	.29
	5622	Lucky Hit	....	....	30.75	83.04	....	....	3.28	1,177.10	759.82	....
	5890	Rayjax	....	....	62.25	84.50	.42	....	....	775.75	1,261.39	5.12
	6007	Sabrina	....	....	....	....	....	....	....	38.75	31.34	....
		Voided Leases	....	....	....	....	....	....	212.48	362,696.87	196,412.90	19.86
		Sundry Claims	....	....	156.00	19.16	.24	....	238.91	9,398.13	5,613.80	1.11
Bulla Bulling	6035	Bernguard	....	....	198.00	38.54	....	....	....	235.50	48.04	....
	6003	Worked Out	....	....	9.50	13.88	....	....	....	145.25	160.09	....
		Voided Leases	....	....	....	....	....	....	....	1,410.56	968.52	....
		Sundry Claims	....	....	....	....	....	5.21	19.60	2,134.51	838.02	....

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 1966					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.*												
Burbanks	G.M.L. 6058	Belgian Queen	....	....	51.00	2.57	....	....	....	51.00	2.57	....
		Voided Leases	....	....	....	....	....	14.90	376.98	420,591.86	306,446.31	521.06
		Sundry Claims	....	....	390.75	67.93	....	55.05	497.55	18,074.85	9,432.22	.93
Cave Rocks	....	Voided Leases	....	....	....	....	....	....	....	8,223.16	1,941.42	....
		Sundry Claims	....	....	34.50	2.61	....	....	50.00	4,850.90	1,117.30	....
Coolgardie	6051	Ada	....	....	45.25	18.78	....	....	....	45.25	18.78	....
	6026	Cyanide North	....	....	....	....	....	....	....	36.25	6.43	....
	6032	El Dorado	....	....	....	....	....	....	....	8.00	8.95	....
	6038	Hillside	....	....	235.00	187.05	....	....	....	235.00	187.05	....
	5844	Jackpot	....	....	....	....	....	....	....	10,248.75	4,261.04	....
	6036	King's Cross	....	....	4.00	4.41	....	....	....	4.00	4.41	....
	5884	Lone Hand	....	....	....	....	....	....	19.85	499.00	84.85	....
	6024	New Cock Shot	....	....	....	....	....	66.05	....	47.00	16.04	.51
	6047	Predjudice	....	....	100.00	10.88	....	....	....	100.00	10.88	....
		Voided Leases	....	....	....	....	....	1,301.71	5,464.54	1,259,542.44	524,008.83	5,730.26
		Sundry Claims	....	....	776.00	175.86	....	236.14	2,966.48	84,719.19	29,605.29	1.90
Eundynie	....	Voided Leases	....	....	....	....	....	3.70	16.09	31,772.98	16,531.34	1.75
		Sundry Claims	....	....	....	....	....	8.85	229.66	698.12	521.20	....
Gibraltar	5723	Lloyd George	....	....	....	....	....	....	....	763.00	176.78	....
		Voided Leases	....	....	....	....	....	....	33.97	38,762.63	20,114.27	....
		Sundry Claims	....	....	21.25	9.37	....	1.39	50.76	3,569.60	1,432.12	....
Gnarlbine	....	Voided Leases	....	....	....	....	....	....	13.95	2,731.75	1,341.60	....
		Sundry Claims	....	....	....	....	....	....	4.90	1,186.10	504.18	....
Hampton Plains	P.P.L. 16A, Loc. 59	C. W. Avard	....	....	72.75	26.80	....	....	....	157.75	59.10	....
	P.P.L. 481, Loc. 59	T. R. Baker	....	....	102.00	40.15	....	....	....	102.00	40.15	....
	P.P.L. 334, Loc. 59	Gold Mines of Kalgoorlie (Aust.) Ltd.	....	....	....	....	....	....	....	3,143.75	1,058.85	....
	P.P.L. 316, Loc. 59; P.P.L. 330, Loc. 59	Gold Mines of Kalgoorlie (Aust.) Ltd.	....	....	651.50	177.28	7.42	....	....	264,074.50	134,770.95	29,880.69
		Prior to transfer to present holders	....	....	....	....	....	....	....	9,346.75	5,081.22	....
	P.P.L. 482, Loc. 59	J. M. McGee	....	....	196.50	33.16	....	....	....	196.50	33.16	....
	P.P.L. 486, Loc. 59	H. Boucher	....	....	13.25	7.92	....	....	....	436.75	104.34	....
	P.P.L. 489, Loc. 59	C. L. Voumard	....	....	....	....	....	....	73.47	77.25	37.77	....
		Cancelled Leases	....	....	....	....	....	2.56	486.33	20,255.46	13,529.32	1.18
		Sundry Claims and Leases	....	....	....	....	....	1.63	132.06	1,957.75	859.58	....

Higginsville	G.M.L. 5647	Fair Play Gold Mine	....	....	....	.98	....	4.42	62.70	28,676.75	3,196.09	.02
		Voided Leases	....	....	....	....	....	....	482.47	46,410.85	22,314.61	160.80
		Sundry Claims	....	....	88.00	22.39	....	....	187.25	3,809.76	1,985.80	....
Larkinville	....	Voided Leases	....	....	....	....	....	22.77	54.44	2,335.16	3,256.49	....
		Sundry Claims	....	....	....	....	....	....	147.20	490.53	1,033.19	....
Logans	G.M.L. 6044	Dorothy Gay	....	....	77.00	365.65	....	....	....	77.00	365.65	....
	6016	Great Lion	....	....	12.00	3.04	....	....	....	529.50	68.95	....
		Voided Leases	....	....	....	....	....	....	11.09	106,660.81	26,931.68	....
		Sundry Claims	....	....	55.68	2,518.13	45.29	6.88	551.62	3,506.03	3,634.96	45.29
Londonderry	....	Voided Leases	....	....	....	....	....	....	95.04	34,155.35	22,238.37	.35
		Sundry Claims	....	....	34.50	6.77	....	16.68	80.78	4,276.42	2,695.59	22.42
Mungari	....	Voided Leases	....	....	....	....	....	....	17.71	1,872.50	458.43	....
		Sundry Claims	....	....	....	....	....	1.77	153.24	3,243.44	781.26	....
Paris	5953, etc.	Paris Gold Mine Pty. Ltd.	....	....	....	....	....	....	....	42,516.00	14,808.24	17,015.61
	5873	Paris West	....	....	....	....	....	....	....	19.00	11.03	....
		Voided Leases	....	....	....	....	....	.88	4.30	15,497.00	8,625.37	79.19
		Sundry Claims	....	....	....	....	....	....	....	2,123.00	521.97	....
Red Hill	....	Voided Leases	....	....	....	....	....	14.87	1,551.81	40,797.40	31,070.65	....
		Sundry Claims	....	....	....	....	....	15.29	95.72	1,496.64	1,126.20	....
Ryan's Find	5999	Little Nipper	....	....	149.50	1,365.52	....	....	3,126.84	241.75	2,469.56	....
		Voided Leases	....	....	....	....	....	....	....	54.16	151.69	....
		Sundry Claims	....	....	....	....	....	....	479.26	193.44	404.91	....
St. Ives	....	Voided Leases	....	....	....	....	....	63.34	146.87	39,318.46	16,208.86	....
		Sundry Claims	....	....	....	....	....	211.67	950.23	4,196.56	1,462.08	....
Wannaway	....	Voided Leases	....	....	....	....	....	....	28.61	1,831.95	1,465.70	....
		Sundry Claims	....	....	....	....	....	....	193.79	1,336.12	1,310.57	....
Widgiemooltha	5834	Harpers	....	....	....	....	....	....	9.54	40.00	93.06	....
	5451, etc.	Paris Gold Mines Pty. Ltd. (Host Group)	....	....	....	....	....	....	....	3,585.00	912.10	486.12
	5451	Host Group	....	....	....	....	....	....	12.75	1,604.15	565.02	....
		Voided Leases	....	....	....	....	....	17.95	1,252.70	22,743.81	11,970.29	.17
		Sundry Claims	....	....	....	....	....	46.49	470.06	16,230.66	6,895.15	.07
	From District generally :—											
	Sundry Parcels treated at :											
		State Battery, Coolgardie....	....	....	....	*249.08	7.19	....	....	771.01	*41,628.19	24.92
		Various Works	....	....	....	....	....	7.75	....	4,375.61	*33,855.21	473.96
		Reported by Banks and Gold Dealers	23.49	....	....	....	....	15,025.61	743.46	48.25	141.36	1.05
		Total	**23.49**	....	**3,566.93**	**5,535.45**	**60.56**	**17,153.56**	**21,800.34**	**2,999,986.75**	**1,544,336.55**	**54,474.63**

KUNANALLING DISTRICT.

Carbine	G.M.L. 1048S	Carbine	....	....	....	....	....	....	....	33.50	17.79	....
		Voided Leases	....	....	....	....	....	....	687.98	85,927.86	52,381.02	....
		Sundry Claims	....	....	92.50	19.98	....	136.27	96.96	6,781.88	2,391.84	....
Chadwin	....	Voided Leases	....	....	....	....	....	....	....	4,837.80	5,298.69	2.50
		Sundry Claims	....	9.57	24.50	12.58	....	14.28	91.93	6,012.05	2,965.65	.25

Table I.—*Production of Gold and Silver from all sources, etc.*—continued.

Mining Centre	Number of Lease	Registered Name of Company or Lease	Total for 1966 Alluvial	Total for 1966 Dollied and Specimens	Total for 1966 Ore treated	Total for 1966 Gold therefrom	Total for 1966 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.

COOLGARDIE GOLDFIELD—continued
KUNANALLING DISTRICT—*continued.*

Mining Centre	Number of Lease	Registered Name of Company or Lease	Total for 1966 Alluvial	Total for 1966 Dollied and Specimens	Total for 1966 Ore treated	Total for 1966 Gold therefrom	Total for 1966 Silver	Total Production Alluvial	Total Production Dollied and Specimens	Total Production Ore treated	Total Production Gold therefrom	Total Production Silver
Dunnsville	....	Voided Leases	....	....	....	....	....	....	828.58	17,548.85	8,657.45	....
		Sundry Claims	....	....	....	....	....	21.00	1,034.08	3,070.96	2,117.32	....
Jourdie Hills	....	Voided Leases	....	....	....	....	....	....	18.00	28,009.74	19,401.09	28.45
		Sundry Claims	....	....	....	....	....	1.86	49.81	2,057.50	927.29	1.05
Kintore	....	Voided Leases	....	....	....	....	....	18.70	169.33	56,822.89	40,044.61	677.88
		Sundry Claims	....	....	37.00	8.56	....	111.91	102.70	5,120.28	2,639.07	....
Kunanalling	1052S	Catherwood	....	....	....	....	....	....	....	234.50	10.44	....
		Voided Leases	....	....	....	....	....	86.13	1,734.92	130,303.61	100,812.73	40.77
		Sundry Claims	....	....	92.00	25.65	....	216.53	976.87	16,964.02	10,286.81	21.67
Kundana	....	Voided Leases	....	....	....	....	....	....	....	465.00	68.12	....
		Sundry Claims	....	....	....	....	....	....	....	475.25	60.38	....
	From District generally :—											
	Sundry Parcels treated at :											
	Gold Fields Aust. Development		....	....	....	....	....	....	....	....	*548.07	....
	Various Works		....	....	....	....	....	42.23	....	1,782.26	5,063.55	....
	Reported by Banks and Gold Dealers		.86	....	....	....	....	872.65	17.93	....	5.85	.49
		Total	**.86**	**9.57**	**246.00**	**66.77**	....	**1,521.56**	**5,809.09**	**366,447.95**	**253,697.77**	**773.06**

Yilgarn Goldfield.

Mining Centre	Number of Lease	Registered Name of Company or Lease	Total for 1966 Alluvial	Total for 1966 Dollied and Specimens	Total for 1966 Ore treated	Total for 1966 Gold therefrom	Total for 1966 Silver	Total Production Alluvial	Total Production Dollied and Specimens	Total Production Ore treated	Total Production Gold therefrom	Total Production Silver
Blackbourne	....	Voided Leases	....	....	....	....	....	....	....	1,282.50	341.37	....
		Sundry Claims	....	....	....	....	....	....	....	392.50	81.15	....
Bullfinch	G.M.L. (3350, etc.)	Great Western Consolidated N.L.	....	....	17.25	37.50	....	....	....	3,319,889.50	457,923.04	126,971.82
		Prior to transfer to present holders	....	....	....	....	....	....	64.80	78,404.34	24,644.88	....
		Voided Leases	....	....	....	....	....	....	10.14	490,643.07	185,701.81	27,963.57
		Sundry Claims	....	....	39.75	78.02	3.83	8.47	45.49	7,679.14	4,292.93	24.17
Corinthian	....	Voided Leases	....	....	....	....	....	....	23.46	284,243.98	58,510.80	4,136.81
		Sundry Claims	....	....	....	....	....	....	2.68	1,088.35	640.61	....
Eenuin	....	Voided Leases	....	....	....	....	....	....	196.74	10,827.31	10,820.07	15.01
		Sundry Claims	....	....	....	....	....	3.16	90.95	2,873.95	2,052.04	4.39
Evanston	....	Voided Leases	....	....	....	....	....	....	79.27	64,533.06	37,402.13	974.56
		Sundry Claims	....	....	....	....	....	4.98	....	648.60	160.61	....

Forrestonia	G.M.L. 4506	Margaret Ellen	....	....	....	....	....	....	....	84.00	21.79	.70
		Voided Leases	....	....	....	....	....	....	....	1,185.00	298.15	....
		Sundry Claims	....	....	....	....	....	....	.49	578.75	285.71	8.47
Golden Valley	3347, etc.	Radio Leases	....	....	....	....	....	....	2.70	46,599.80	66,874.97	2,002.82
		Voided Leases	....	....	....	....	....	....	36.34	40,367.92	29,278.11	29.54
		Sundry Claims	....	....	....	....	....	4.58	241.60	6,679.07	4,950.53	2.34
Greenmount	....	Voided Leases	....	....	....	....	....	45.99	21.62	125,905.64	31,667.08	961.19
		Sundry Claims	....	....	36.50	6.95	16.38	.46	4.27	3,237.33	850.65	22.14
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	....	Voided Leases	....	....	....	....	....	....	74.78	314,609.67	63,028.26	4,364.45
		Sundry Claims	....	....	48.00	4.06	....	21.12	96.11	4,849.62	1,474.27	1.59
Kennyville	3875	Victoria	....	....	....	....	....	....	....	5,458.00	1,206.32	2.12
		Voided Leases	....	....	....	....	....	....	18.76	55,876.63	21,625.66	.59
		Sundry Claims	....	....	....	....	....	....	5.06	8,729.00	2,352.28	.56
Koolyanobbing	....	Voided Leases	....	....	....	....	....	....	.99	1,768.05	972.77	....
		Sundry Claims	....	....	....	....	....	.26	17.33	724.85	339.23	....
Marvel Loch	4499	Bohemia	....	....	....	....	....	....	....	44.00	18.31	.98
	4434	Cornwall	....	....	....	....	....	....	....	17,790.25	2,466.84	528.00
	4039	Cromwell	....	....	....	....	....	....	....	1,059.50	164.51	.07
	3942, etc.	Edwards Reward Leases	....	....	....	....	....	....	....	75,726.75	32,480.80	399.11
		Prior to transfer to present holders	....	....	....	....	....	....	....	5,946.00	4,401.11	....
	4034	Firelight	....	....	....	....	....	....	2.68	6,695.75	943.52	.15
	3724	Frances Firness	....	....	715.50	265.21	13.03	....	512.87	22,389.25	9,944.66	268.58
	4230	May Queen	....	....	....	....	....	....	....	286.00	43.42	....
	4035	Undaunted	....	....	75.50	4.11	.29	....	....	1,070.00	126.88	.39
		Voided Leases	....	....	....	....	....	....	1,546.04	1,216,170.33	278,690.31	16,053.56
		Sundry Claims	....	....	212.25	13.14	.48	11.35	809.31	38,812.34	13,915.92	85.85
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	....	....	88.75	23.88	.83	2.03	1.69	680.25	127.21	1.23
	4515	Speedie	....	....	....	....	....	....	....	230.50	13.94	.61
		Voided Leases	....	....	....	....	....	....	....	306,531.65	158,527.11	....
		Sundry Claims	....	....	....	....	....	1,643.48	18.19	450.25	387.14	....
Mt. Rankin	G.M.L. 4462	Golden View	....	....	....	....	....	....	316.90	142.00	284.87	2.38
	4461	Marjorie Glen Reward	....	....	....	....	....	....	191.46	3,210.55	4,047.72	4.85
		Voided Leases	....	....	....	....	....	3.84	5.20	6,991.87	1,350.36	24.55
		Sundry Claims	....	....	....	....	....	....	1.85	771.00	956.57	....
Parker's Range	4508	Buffalo	....	10.36	216.50	34.43	.82	....	10.36	834.25	154.07	4.52
	4512	Constance Una	....	....	175.25	240.81	9.26	....	....	551.25	706.87	37.91
		Voided Leases	....	....	....	....	....	.42	270.76	64,082.85	32,812.23	27.43
		Sundry Claims	....	....	99.50	4.83	.29	6.59	303.93	13,855.30	5,657.29	2.74
Southern Cross	4424	Excelsior	....	....	....	....	....	....	....	166.00	17.19	1.14
	4510	Three Boys	....	....	....	....	....	....	....	.50	69.69	6.03
		Voided Leases	....	....	....	....	....	4.89	261.35	892,908.18	313,906.67	20,276.32
		Sundry Claims	....	....	32.25	1.01	.03	95.90	648.99	8,680.66	2,748.29	7.93

Table I.—*Production of Gold and Silver from all sources, etc.*—continued.

Mining Centre	Number of Lease	Registered Name of Company or Lease	Total for 1966					Total Production				
			Alluvial	Dollied and Specimens	Ore treated	Gold therefrom	Silver	Alluvial	Dollied and Specimens	Ore treated	Gold therefrom	Silver
			Fine ozs.	Fine ozs.	Tons (2,240 lb.)	Fine ozs.	Fine ozs.	Fine ozs.	Fine ozs.	Tons (2,240 lb.)	Fine ozs.	Fine ozs.
		YILGARN GOLDFIELD—continued										
Westonia	....	Voided Leases	....	....	....	....	....	....	4.06	597,118.14	381,435.37	5,104.07
		Sundry Claims	....	....	....	....	....	9.51	64.96	4,310.76	2,823.33	.72
		From Goldfield generally :—										
		Sundry Parcels treated at :										
		State Battery, Marvel Loch	....	....	58.00	*295.51	249.94	....	....	147.00	*3,449.76	264.50
		Various Works	....	....	....	....	....	....	....	624.73	*117,106.07	820.41
		Reported by Banks and Gold Dealers	....	....	....	....	....	325.29	81.41	.60	170.54	....
		Total	....	**10.36**	**1,815.00**	**1,009.46**	**295.18**	**2,198.76**	**6,332.39**	**8,284,218.12**	**2,438,350.66**	**213,832.27**
		Dundas Goldfield.										
Beete	....	Voided Leases	....	....	....	....	....	....	....	2,498.50	1,848.98	89.09
		Sundry Claims	....	....	....	....	....	....	....	416.50	392.87	....
Buldania	....	Voided Leases	....	....	....	....	....	....	3.02	846.05	708.99	....
		Sundry Claims	....	....	....	....	....	....	39.25	1,324.27	861.36	.72
Dundas	....	Voided Leases	....	....	....	....	....	1.88	28.02	6,241.98	2,560.53	155.02
		Sundry Claims	....	....	14.50	2.36	.17	.76	413.85	2,289.75	1,167.63	20.25
Norseman	G.M.L. 1936, etc.	Central Norseman Gold Corporation N.L.	....	....	188,647.00	98,921.73	78,616.60	....	....	4,149,385.20	1,951,984.39	1,275,999.34
		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
	(1939)	Young Bill	....	....	5.00	4.56	.43	....	....	5.00	4.56	.43
		Voided Leases	....	....	....	....	....	14.27	10,601.15	917,065.17	601,851.09	39,001.96
		Sundry Claims	....	....	24.50	3.73	.07	1,052.25	3,523.62	49,803.95	22,642.11	228.07
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 :										
		State Battery, Norseman	....	....	....	*130.50	10.65	....	....	427.89	*25,844.35	1,080.10
		Various Works	....	....	....	....	....	....	54.52	1,029.89	*15,124.31	2,588.91
		Reported by Banks and Gold Dealers	....	....	....	....	....	1,186.36	49.59	47.50	21.37	1.04
		Total	....	....	**188,691.00**	**99,062.88**	**78,627.92**	**2,255.52**	**16,400.63**	**6,195,778.12**	**2,924,045.65**	**1,693,874.49**
		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.C.'s 35, etc.	Ravensthorpe Copper Mines N.L.	....	....	....	§1,389.34	4,439.14	....	....	....	§16,735.18	49,528.51
		Prior to transfer to present holders	....	....	....	....	....	....	....	....	§1.99	....
		Voided Leases	....	....	....	....	....	....	141.80	24,730.01	26,073.97	4,500.55
		Sundry Claims	....	....	....	....	....	163.96	7.68	7,267.82	3,197.97	41.12
West River	....	Voided Leases	....	....	....	....	....	....	....	....	10.34	31.06
		Sundry Claims	....	....	....	....	....	....	....	....	6.60	3.44
From Goldfield generally :—												
Sundry Parcels treated at :												
F. E. Daw (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	....	....	....	**1,389.34**	**4,439.14**	**607.11**	**823.32**	**130,659.24**	**120,809.81**	**65,671.59**

Northampton Mineral Field.

Northampton	....	Sundry Leases and Claims	....	....	....	....	....	....	....	....	....	†5,185.58
		Total	....	....	....	....	....	....	....	....	....	**†5,185.58**

South-West Mineral Field.

Burracoppin	....	Voided Leases	....	....	....	....	....	....	....	710.85	706.38	....
		Sundry Claims	....	....	....	....	....	....	.98	405.25	270.17	....
Donnybrook	....	Voided Leases	....	....	....	....	....	23.24	....	1,613.30	816.23	....
		Sundry Claims	....	....	....	....	....	44.01	43.03	119.50	15.71	15.18
Lake Grace	....	Voided Leases	....	....	....	....	....	....	....	294.00	154.39	....
		Sundry Claims	....	....	....	....	....	....	....	81.75	81.44	....
Ongerup	G.M.L. 103H	Hornblende	....	....	....	....	....	....	....	24.50	2.85	....
		Sundry Claims	....	....	....	....	....	....	1.58	.33	1.74	....
From Mineralfield generally :—												
Miscellaneous voided leases and sundry claims			....	....	....	....	....	245.83	3.07	1,472.10	353.19	....
		Total	....	....	....	....	....	**313.08**	**48.66**	**4,721.58**	**2,402.10**	**15.18**

Outside Proclaimed Goldfield.

Warburton Range	M.L. 10P	T. Simms	....	....	....	....	§1,259.58	....	....	....	....	§1,259.58
		Total	....	....	....	....	**§1,259.58**	....	....	....	....	**§1,259.58**

State Generally.

Sundry Parcels treated at :												
Various Works			....	....	....	....	....	....	....	27.00	9,009.75	31,521.73
Reported by Banks and Gold Dealers			....	....	....	53.09	....	1,194.95	1,111.85	....	1,020.62	1,140.93
		Total	....	....	....	**53.09**	....	**1,194.95**	**1,111.85**	**27.00**	**10,030.37**	**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 1966.

Goldfield	District	District: Alluvial	District: Dollied and Specimens	District: Ore Treated	District: Gold Therefrom	District: Total Gold	District: Silver	Goldfield: Alluvial	Goldfield: Dollied and Specimens	Goldfield: Ore Treated	Goldfield: Gold Therefrom	Goldfield: Total Gold	Goldfield: Silver
		Fine ozs.	Fine ozs.	Tons (2,240 lb.)	Fine ozs.	Fine ozs.	Fine ozs.	Fine ozs.	Fine ozs.	Tons (2,240 lb.)	Fine ozs.	Fine ozs.	Fine ozs.
Kimberley	....	....	....	....	....	....	....	....	7.97	....	10.14	18.11	....
West Kimberley	....	....	....	....	....	....	....	....	....	....	....	....	4,119.98
West Pilbara	....	....	....	....	....	....	....	....	....	....	....	....	....
Pilbara	Marble Bar	....	....	1,163.00	916.67	916.67	65.29	....	....	1,163.00	916.67	916.67	65.29
	Nullagine	....	....	....	....	....	....						
Ashburton	....	....	....	....	....	....	....	....	....	....	....	....	....
Gascoyne	....	....	....	....	....	....	....	....	....	143.00	350.08	350.08	16.24
Peak Hill	....	....	....	....	....	....	....	....	6.18	....	....	6.18	.17
East Murchison	Lawlers	....	....	2,004.00	900.21	900.21	7.62						
	Wiluna	....	....	....	....	....	....	....	....	2,242.25	1,044.36	1,044.36	16.78
	Black Range	....	....	238.25	144.15	144.15	9.16						
Murchison	Cue	10.81	4.74	....	37.61	53.16	40.69						
	Meekatharra	3.54	79.99	4,520.51	768.44	851.97	10.08	21.10	84.73	161,846.51	42,366.47	42,472.30	3,406.79
	Day Dawn	.44	....	....	....	.44	....						
	Mt. Magnet	6.31	....	157,326.00	41,560.42	41,566.73	3,356.02						
Yalgoo	....	....	....	....	....	....	....	7.00	....	....	....	7.00	.65
Mt. Margaret	Mt. Morgans	....	....	140.00	26.24	26.24	....						
	Mt. Malcolm	....	....	633.50	688.27	688.27	8.05	....	....	773.50	714.51	714.51	8.05
	Mt. Margaret	....	....	....	....	....	....						
North Coolgardie	Menzies	....	....	26,536.85	9,901.77	9,901.77	1,422.79						
	Ularring	....	....	1,168.75	369.14	369.14	....	.27	....	27,781.10	10,335.34	10,335.61	1,424.27
	Niagara	....	....	11.50	4.13	4.13	....						
	Yerilla	.27	....	64.00	60.30	60.57	1.48						
Broad Arrow	....	....	....	....	....	....	....	3.30	....	8,634.10	2,271.12	2,274.42	22.39
North-East Coolgardie	Kanowna	2.75	108.94	408.25	337.31	449.00	....	2.75	108.94	498.25	375.24	486.93	....
	Kurnalpi	....	....	90.00	37.93	37.93							
East Coolgardie	East Coolgardie	4.32	1.30	2,221,461.55	461,115.49	461,121.11	142,965.52	4.32	1.30	2,221,615.55	461,258.68	461,264.30	142,965.84
	Bulong	....	....	154.00	143.19	143.19	.32						
Coolgardie	Coolgardie	23.49	....	3,566.93	5,535.45	5,558.94	60.56	24.35	9.57	3,812.93	5,602.22	5,636.14	60.56
	Kunanalling	.86	9.57	246.00	66.77	77.20	....						
Yilgarn	....	....	....	....	....	....	....	....	10.36	1,815.00	1,009.46	1,019.82	295.18
Dundas	....	....	....	....	....	....	....	....	....	188,691.00	99,062.88	99,062.88	78,627.92
Phillips River	....	....	....	....	....	....	....	....	....	....	1,389.34	1,389.34	4,439.14
South-West Mineral Field	....	....	....	....	....	....	....	....	....	....	....	....	....
Northampton Mineral Field	....	....	....	....	....	....	....	....	....	....	....	....	....
State Generally	....	....	....	....	....	....	....	....	....	....	53.09	53.09	....
Outside Proclaimed Goldfield	....	....	....	....	....	....	....	....	....	....	....	....	1,259.58
Total	....	....	....	....	....	....	....	**63.09**	**229.05**	**2,619,016.19**	**626,759.60**	**627,051.74**	**236,728.83**

TABLE III.

Return showing total production reported to the Mines Department, and respective Districts and Goldfields from whence derived, to 31st December, 1966.

Goldfield	District	District: Alluvial	District: Dollied and Specimens	District: Ore Treated	District: Gold Therefrom	District: Total Gold	District: Silver	Goldfield: Alluvial	Goldfield: Dollied and Specimens	Goldfield: Ore Treated	Goldfield: Gold Therefrom	Goldfield: Total Gold	Goldfield: Silver
		Fine ozs.	Fine ozs.	Tons (2,240 lb.)	Fine ozs.	Fine ozs.	Fine ozs.	Fine ozs.	Fine ozs.	Tons (2,240 lb.)	Fine ozs.	Fine ozs.	Fine ozs.
Kimberley	....	....	....	....	....	....	....	9,079.68	3,035.43	22,931.90	17,292.01	29,407.12	128.76
West Kimberley	....	....	....	....	....	....	....	1.30	24.68	1.00	2.49	28.47	37,317.55
West Pilbara	....	....	....	....	....	....	....	6,339.37	374.74	24,900.96	24,317.02	31,031.13	1,910.66
Pilbara	Marble Bar	15,510.47	4,569.14	344,868.72	332,682.24	352,761.85	33,068.05	26,020.00	7,478.83	494,911.14	468,139.45	501,638.28	34,148.84
	Nullagine	10,509.53	2,090.69	150,042.42	135,457.21	148,876.43	1,080.79						
Ashburton	....	....	....	....	....	....	....	9,268.52	482.46	6,807.10	2,913.43	12,664.41	41,971.38
Gascoyne	....	....	....	....	....	....	....	698.49	121.33	1,185.75	2,533.35	3,353.17	87.17
Peak Hill	....	....	....	....	....	....	....	3,387.79	5,377.97	783,070.73	322,738.34	331,504.10	3,794.07
East Murchison	Lawlers	7,103.51	2,343.19	2,019,123.67	826,369.72	835,816.42	27,268.77						
	Wiluna	236.48	1,254.11	8,873,649.69	1,872,319.97	1,873,810.56	10,322.32	9,010.95	22,207.27	12,624,468.08	3,654,080.21	3,685,298.43	60,324.41
	Black Range	1,670.96	18,609.97	1,731,694.72	955,390.52	975,671.45	22,733.32						
Murchison	Cue	5,135.12	9,109.73	6,815,391.31	1,402,690.86	1,416,935.71	274,799.68						
	Meekatharra	14,704.53	18,579.13	2,321,890.57	1,311,236.37	1,344,520.03	5,277.43	25,773.70	59,498.41	14,863,276.13	5,898,425.99	5,983,698.10	512,583.62
	Day Dawn	3,291.61	11,341.80	2,037,595.63	1,375,641.81	1,390,275.22	169,447.42						
	Mt. Magnet	2,642.44	20,467.75	3,688,398.62	1,808,856.95	1,831,967.14	63,059.09						
Yalgoo	....	....	....	....	....	....	....	1,815.77	3,224.00	443,349.58	264,036.39	269,076.16	1,523.06
Mt. Margaret	Mt. Morgans	3,574.87	9,401.98	1,218,139.31	718,011.55	730,988.40	5,831.33						
	Mt. Malcolm	4,066.98	16,668.99	7,753,565.97	3,070,333.64	3,091,069.61	190,790.01	11,789.38	35,425.32	11,499,878.52	4,962,388.75	5,009,603.45	262,812.04
	Mt. Margaret	4,147.53	9,354.35	2,528,173.24	1,174,043.56	1,187,545.44	66,190.70						
North Coolgardie	Menzies	1,696.69	7,032.09	1,945,211.98	1,430,909.37	1,439,638.15	38,651.25						
	Ularring	129.66	7,298.59	536,986.45	446,956.29	454,384.54	22,286.97	4,857.37	19,969.57	3,723,526.23	2,584,852.01	2,609,678.95	72,000.63
	Niagara	1,718.48	1,821.77	944,448.02	528,582.27	532,122.52	5,716.17						
	Yerilla	1,312.54	3,817.12	296,879.78	178,404.08	183,533.74	5,346.24						
Broad Arrow	....	....	....	....	....	....	....	21,995.82	28,005.48	1,411,648.89	752,197.12	802,198.42	5,671.45
North-East Coolgardie	Kanowna	106,546.01	13,635.61	1,010,727.81	628,017.50	748,199.12	3,049.28	119,383.28	21,934.52	1,025,200.88	647,180.55	788,498.35	3,061.99
	Kurnalpi	12,837.27	8,298.91	14,473.07	19,163.05	40,299.23	12.71						
East Coolgardie	East Coolgardie	33,733.04	41,188.12	90,105,842.49	36,952,966.12	37,027,887.28	6,046,891.93	61,138.55	57,224.89	90,294,353.82	37,086,083.52	37,204,446.96	6,046,991.69
	Bulong	27,405.51	16,036.77	188,511.33	133,117.40	176,559.68	99.76						
Coolgardie	Coolgardie	17,153.56	21,800.34	2,999,986.78	1,544,336.55	1,583,290.45	54,474.63	18,675.12	27,609.43	3,366,434.73	1,798,034.32	1,844,318.87	55,247.69
	Kunanalling	1,521.56	5,809.09	366,447.95	253,697.77	261,028.42	773.06						
Yilgarn	....	....	....	....	....	....	....	2,198.76	6,332.39	8,284,218.12	2,438,350.66	2,446,881.81	213,832.27
Dundas	....	....	....	....	....	....	....	2,255.52	16,400.63	6,195,778.12	2,924,045.65	2,942,701.80	1,693,874.49
Phillips River	....	....	....	....	....	....	....	607.11	823.32	130,659.24	120,809.81	122,240.24	65,671.59
South-West Mineral Field	....	....	....	....	....	....	....	313.08	48.66	4,721.58	2,402.10	2,763.84	15.18
Northampton Mineral Field	....	....	....	....	....	....	....	....	....	....	....	....	5,185.58
State Generally	....	....	....	....	....	....	....	1,194.95	1,111.85	27.00	10,030.37	12,337.17	32,662.66
Outside Proclaimed Goldfield	....	....	....	....	....	....	....	....	....	....	....	....	1,259.58
Total	....	....	....	....	....	....	....	**335,804.51**	**316,711.18**	**155,201,349.50**	**63,980,853.54**	**64,633,369.23**	**9,152,076.36**

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	2,294
1887	4,359·37	....	4,359·37	37,036
1888	3,124·82	....	3,124·82	26,546
1889	13,859·52	....	13,859·52	117,742
1890	20,402·42	....	20,402·42	173,328
1891	27,116·14	....	27,116·14	230,364
1892	53,271·65	....	53,271·65	452,568
1893	99,202·50	....	99,202·50	842,770
1894	185,298·73	....	185,298·73	1,574,198
1895	207,110·20	....	207,110·20	1,759,498
1896	251,618·69	....	251,618·69	2,137,616
1897	603,846·44	....	603,846·44	5,129,954
1898	939,489·49	....	939,489·49	7,981,394
1899	1,283,360·25	187,244·41	1,470,604·66	12,493,464
1900	894,387·27	519,923·59	1,414,310·86	12,015,220
1901	923,698·96	779,729·56	1,703,416·52	14,471,308
1902	707,039·75	1,163,997·60	1,871,037·35	15,895,322
1903	833,685·78	1,231,115·62	2,064,801·40	17,541,438
1904	810,616·04	1,172,614·03	1,983,230·07	16,848,452
1905	655,089·88	1,300,226·00	1,955,315·88	16,611,308
1906	562,250·59	1,232,296·01	1,794,546·60	15,245,498
1907	431,803·14	1,265,750·45	1,697,553·50	14,421,500
1908	356,353·96	1,291,557·17	1,647,911·13	13,999,762
1909	386,370·58	1,208,898·83	1,595,269·41	13,552,548
1910	233,970·34	1,236,661·68	1,470,632·02	12,493,696
1911	160,422·28	1,210,445·24	1,370,867·52	11,646,150
1912	83,577·12	1,199,080·87	1,282,657·99	10,896,770
1913	86,255·13	1,227,788·15	1,314,043·28	11,163,402
1914	51,454·65	1,181,522·17	1,232,976·82	10,474,704
1915	17,340·47	1,192,771·23	1,210,111·70	10,280,456
1916	26,742·17	1,034,655·87	1,061,398·04	9,017,064
1917	9,022·49	961,294·67	970,317·16	8,243,292
1918	15,644·12	860,867·03	876,511·15	7,446,366
1919	6,445·89	727,619·90	734,065·79	7,237,018
1920	5,261·13	612,581·00	617,842·13	7,197,862
1921	7,170·74	546,559·92	553,730·66	5,885,052
1922	5,320·16	532,926·12	538,246·28	5,051,624
1923	5,933·82	498,577·59	504,511·41	4,464,372
1924	2,585·20	482,449·78	485,034·98	4,511,854
1925	3,910·59	437,341·56	441,252·15	3,748,640
1926	3,188·22	434,154·98	437,343·20	3,715,430
1927	3,359·10	404,993·41	408,352·51	3,469,144
1928	3,339·30	390,069·19	393,408·49	3,342,186
1929	3,037·12	374,138·96	377,176·08	3,204,284
1930	1,753·09	415,765·00	417,518·09	3,728,884
1931	1,726·66	508,845·36	510,572·02	5,996,274
1932	3,887·07	601,674·33	605,561·40	8,807,284
1933	2,446·97	634,760·40	637,207·37	9,772,508
1934	3,520·40	647,817·95	661,338·35	11,117,746
1935	9,868·71	639,180·38	649,049·09	11,404,298
1936	55,024·58	791,183·21	846,207·79	14,747,078
1937	71,646·91	928,999·84	1,000,646·75	17,487,510
1938	113,620·06	1,054,171·13	1,167,791·19	20,726,046
1939	98,739·88	1,115,497·76	1,214,237·64	23,685,928
1940	71,680·47	1,119,801·08	1,191,481·55	25,393,006
1941	65,925·94	1,043,391·96	1,109,317·90	23,702,890
1942	15,676·48	832,503·97	848,180·45	17,730,990
1943	6,408·34	540,057·08	546,475·42	11,421,338
1944	1,824·99	464,439·76	466,264·75	9,799,994
1945	5,029·38	463,521·34	468,550·72	10,021,082
1946	6,090·14	610,873·52	616,963·66	13,280,138
1947	5,220·09	698,666·29	703,886·38	15,151,148
1948	4,653·72	660,332·07	664,985·79	14,313,818
1949	4,173·14	644,252·48	648,425·62	15,925,616
1950	4,161·53	606,171·88	610,333·41	18,932,540
1951	5,589·45	622,189·64	627,779·09	19,450,686
1952	9,608·62	720,366·44	729,975·06	23,695,834
1953	5,396·30	818,515·65	823,911·95	26,598,184
1954	3,089·08	847,451·09	850,540·17	26,627,236
1955	4,091·55	837,913·72	842,005·23	26,351,118
1956	2,331·10	810,048·68	812,379·78	25,411,162
1957	2,042·27	894,638·71	896,680·98	28,076,370
1958	1,810·69	865,376·80	867,187·49	27,109,868
1959	2,321·99	864,286·87	866,608·86	27,083,858
1960	2,068·66	853,690·02	855,758·68	26,743,322
1961	2,942·58	868,902·39	871,844·97	27,413,780
1962	4,539·02	854,829·18	859,368·20	26,871,460
1963	4,665·37	795,546·34	800,211·71	25,035,372
1964	3,070·91	709,776·09	712,847·00	22,299,886
1965	2,996·56	656,440·42	659,436·98	20,722,164
1966	1,462·05	627,314·65	628,776·70	19,765,287
	11,598,699·09	54,569,056·07	66,167,755·16	$A1,029,452,197

	1965	1966
	$A	$A
Estimated Mint value of above production	1,001,747,524	1,021,396,797
Overseas Gold Sales Premium distributed by Gold Producers Association, 1920–1924	5,179,204	5,179,204
Overseas Gold Sales Premium distributed by Gold Producers Association from 1952	2,760,182	2,876,196
Estimated Total	$A1,009,686,910	$A1,029,452,197
Bonus paid by Commonwealth Government under Commonwealth Bounty Act, 1930	322,896	322,896
Subsidy paid by Commonwealth Government under Gold Mining Industry Assistance Act, 1954, from 1955	12,585,208	16,135,700
Gross estimated value of gold won	$A1,022,595,014	$A1,045,910,793

TABLE V.

Quantity and Value of Minerals, other than Gold, Reported during the year 1966

Number of Lease, Claim or Area	Goldfield or Mineral Field	Registered Name of Producer	Quantity Long Tons	Metallic Content	Value $A
		ALUMINA (From Bauxite)	Alumina Recovered Tons		
M.L. 1SA	South-West	Western Aluminium N.L.	243,152.00	....	14,589,120.00 (*f*)
		ASBESTOS (Chrysotile)			
M.C. 98L, etc.	Pilbara	Stubbs, S. H.	119.01	....	19,326.10 (*b*)
		ASBESTOS (Crocidolite)			
M.C. 53, etc.	West Pilbara	Australian Blue Asbestos Pty. Ltd.	11,464.57	....	2,414,905.46 (*b*)
		BARYTES			
M.C. 511H	South-West	Ilich, J.	652.00	....	13,040.00
P.A. 3615N	Murchison	Ward, I. E.	20.00	....	260.00
P.A. 3626N	Murchison	Ward, C. A.	426.65	....	5,538.50
M.C. 20N	Murchison	Universal Milling Co. Pty. Ltd.	711.00	....	7,821.00
			1,809.65	....	26,659.50 (*a*)
		BENTONITE (See Clays)			
		BERYL (*g*) (*h*)		BeO Units	
M.C. 27	Yalgoo	Gray, D. E. C. and Party	1.03	12.40	298.05
P.A. 2640	Yalgoo	Phillips, E. R.	11.60	134.68	2,693.80
			12.63	147.08	2,991.85 (*b*)
		BISMUTH	Lb.	Lb.	
P.A. 2732	Pilbara	Williams, T.	95.70	67.00	88.00 (*b*)
		BUILDING STONE (Granite Facing Stone)			
M.C. 719H	South-West	Crawford Quarries Pty. Ltd.	77.00	....	3,080.00 (*c*)
		BUILDING STONE (Quartzite)			
M.C. 1158H, etc.	South-West	House, R. P.	1,280.00	....	5,120.00 (*c*)
		BUILDING STONE (Sandstone)			
M.C. 990H	South-West	Caporn, C. A.	42.00	....	252.00
M.C. 1036H	South-West	Caporn, C. A.	206.00	....	1,236.00
			248.00	....	1,488.00 (*a*)
		BUILDING STONE (Spongolite)			
Q.A. 1, etc.	Phillips River	Frayne, W. L.	64.00	....	312.00
M.C. 1062H	South-West	Worth, H., Kearney, P. F., King, P. A.	5.00	....	60.00
			69.00	....	372.00 (*c*)
		CLAYS (Bentonite)			
M.C. 907H, etc.	South-West	Universal Milling Co. Pty. Ltd.	193.00	....	579.00
M.C. 282H, etc.	South-West	Collins, A. C.	320.50	....	1,602.50
M.C. 1042H, etc.	South-West	Noonan, E. J.	50.00	....	400.00
			563.50	....	2,581.50 (*a*)
		CLAYS (Cement Clay)			
M.C. 492H, etc.	South-West	Cockburn Cement Pty. Ltd.	15,675.00	....	39,187.00
M.C. 1091H, etc.	South-West	Bell Bros. Pty. Ltd.	6,249.00	....	6,748.92
M.C. 788H, etc.	South-West	Bell Bros. Pty. Ltd.	2,000.00	....	5,600.00
			23,924.00	....	51,535.92 (*c*)
		CLAYS (Fireclay)			
M.C. 504H, etc.	South-West	Brisbane & Wunderlich Ltd.	1,263.00	....	2,715.45
M.C. 522H, etc.	South-West	Bridge, J. S. & T. D.	24,954.00	....	70,370.30
M.C. 304H, etc.	South-West	Clackline Refractories Ltd.	3,363.00	....	6,726.00
M.C. 685H	South-West	Kargotich, T. J. P. & S.	1,000.00	....	2,000.00
M.C. 732H	South-West	Midland Brick Co. Pty. Ltd.	28,967.00	....	28,967.00
Private Property	South-West	*Unspecified Producers	38,940.35	....	58,411.60
			98,487.35	....	169,190.35 (*c*)

* From Private Property not held under the Mining Act.

Quantity and Value of Minerals, other than Gold, Reported during the year 1966

Number of Lease, Claim or Area	Goldfield or Mineral Field	Registered Name of Producer	Quantity Long Tons	Metallic Content	Value $A
		CLAYS (Kaolin)			
M.C. 247H, etc.	South-West	Linton, J. B.	150.00	....	900.00 (*a*)
		CLAYS (White Clay-Ball Clay)			
M.C. 19E	East Coolgardie	Gardner, J. A.	50.00	....	300.00
M.C. 109H	South-West	H. L. Brisbane & Wunderlich	962.00	....	7,696.00
			1,012.00	....	7,996.00 (*c*)
		CLAYS (Brick, Pipe and Tile Clay)*			
Private Property	South-West	Stoneware Pipes and Tiles Pty. Ltd.	2,846.00	....	7,684.20
Private Property	South-West	Stoneware Pipes and Tiles Pty. Ltd.	14,540.00	....	29,480.00
Private Property	South-West	Stoneware Pipes and Tiles Pty. Ltd.	5,081.00	....	10,162.00
Private Property	South-West	Stoneware Pipes and Tiles Pty. Ltd.	720.00	....	1,440.00
Private Property	South-West	Swaby, F. W.	23,000.00	....	57,500.00
Private Property	South-West	†Unspecified Producers	36,904.00	....	20,298.00
			83,091.00	....	126,564.20 (*c*)

* Incomplete. † From Private Property not held under the Mining Act.

Number of Lease, Claim or Area	Goldfield or Mineral Field	Registered Name of Producer	Quantity Long Tons	Metallic Content	Value $A
		COAL			
C.M.L. 448, etc.	Collie	Griffin Coal Mining Co. Ltd.	567,838.75	....	1,647,946.85
C.M.L. 437, etc.	Collie	Western Collieries Ltd.	493,255.90	....	2,914,140.39
			1,061,094.65	....	4,562,087.24 (*e*)
		COPPER ORE AND CONCENTRATES (*g*) (*h*)		Copper Units	
M.C. 35, etc.	Phillips River	Ravensthorpe Copper Mines N.L.	3,116.02	62,391.00	476,166.01
M.C. 10P	Outside Proclaimed	T. Simms ; Western Mining Corporation	152.27	5,399.00	41,968.25
			3,268.29	67,790.00	518,134.26 (*b*)
		CUPREOUS ORE AND CONCENTRATES (Fertiliser)		Assay Cu. %	
M.C. 382L	Pilbara	McPherson, K. J.	62.84	21.06	8,460.00
Crown Land	Pilbara	Crown Lands—District Generally	3.13	5.00	55.10
P.A. 3628N	Murchison	Rinaldi, L. V.	2.00	15.10	163.68
P.A. 1629	East Murchison	Sawyer, H. A.	6.29	10.40	277.90
P.A. 1684F	Mt. Margaret	Gray, F.	16.74	10.14	653.90
M.L. 78P	Peak Hill	Motter, G.	15.09	9.63	581.10
M.C. 97P	Peak Hill	Alac, M.	122.40	25.16	20,505.08
M.C. 665P, etc.	Peak Hill	Lee, R.	(*i*) 26.44	21.99	4,475.68
M.L. 68P	Peak Hill	Thaduna Copper Mining Co. Pty. Ltd.	(*i*) 488.00	12.50	42,788.00
M.L. 10P	Outside Proclaimed	Western Mining Corporation ; T. Simms	201.34	10.75	9,396.76
Crown Land	Outside Proclaimed	Crown Land—District Generally	18.00	8.50	596.70
			962.27	14.11	87,953.90 (*a*) (*b*)
		DIATOMACEOUS EARTH (Calcined)			
M.C. 982H	South-West	Universal Milling Co. Pty. Ltd.	45.50	....	1,955.00 (*c*)
		DOLOMITE			
M.L. 9M, etc.	Murchison	Westralian Ores Pty. Ltd.	5.00	....	75.00 (*a*)
		FELSPAR			
M.L. 80, etc.	Coolgardie	Australian Glass Manuf. Co. Pty. Ltd.	1,282.00	....	18,050.16 (*a*)
		FULLERS EARTH (See Clays)			
		GLASS SAND			
M.C. 417H	South-West	Australian Glass Manuf. Co. Pty. Ltd.	12,369.00	....	16,482.30
M.C. 1071H	South-West	Ready Mix Concrete (W.A.) Pty. Ltd.	15,850.00	....	*
			28,219.00	....	16,482.30 (*c*)

* Value not available for publication.

TABLE V.—*Quantity and Value of Minerals, other than Gold, Reported during the Year 1966—continued*

Number of Lease, Claim or Area	Goldfield or Mineral Field	Registered Name of Producer	Quantity Long Tons	Metallic Content	Value $A
		GYPSUM			
M.C. 30, etc.	Yilgarn	Ajax Plaster Co. Pty. Ltd.	13,714.00	....	24,179.00
M.C. 51, etc.	Yilgarn	H. B. Brady Co. Pty. Ltd.	9,659.00	....	24,147.50
M.C. 9, etc.	Yilgarn	West Australian Plaster Mills	13,500.00	....	19,574.60
M.C. 12, etc.	Dundas	McDonald & Whitfield	300.00	....	300.00
M.C. 612H, etc.	South-West	*Hewitt, B.	2,983.00	....	8,381.00
M.C. 485H, etc.	South-West	Swan Portland Cement	1,728.00	....	3,291.00
			41,884.00	....	79,873.10 (*a*)

* For Plaster Mills of Wishpool.

Plaster of Paris reported as manufactured during the year being 21,078.00 tons from 30,299.00 tons of Gypsum by five Companies. Gypsum used in the manufacture of Cement = 13,058.00 tons.

Number of Lease, Claim or Area	Goldfield or Mineral Field	Registered Name of Producer	Quantity Long Tons	Metallic Content	Value $A
		IRON ORE (Pig Iron Recovered)	Pig Iron Recovered Tons		
T.R. 1258H	Yilgarn	Charcoal Iron and Steel Industry	56,075.00	....	2,865,048.00 (*c*) (*d*)

Ore treated 93,740.00 tons—Average Assay = 62.00% Fe.

Number of Lease, Claim or Area	Goldfield or Mineral Field	Registered Name of Producer	Quantity Long Tons	Metallic Content	Value $A
		IRON ORE (Exported E. States)		Av. Assay Fe%	
M.L. 10, etc.	West Kimberley	Dampier Mining Co. Ltd.	1,251,383.00	63.90	5,180,598.91
M.L. 50, etc.	West Kimberley	Dampier Mining Co. Ltd.	1,363,778.00	63.61	
			2,615,161.00	63.75	5,180,598.91 (*b*)
		IRON ORE (Exported O/Seas.)		Av. Assay Fe%	
M.L. 50, etc.	West Kimberley	Dampier Mining Co. Ltd.	141,346.00	65.79	1,045,711.09
235 S.A.	Pilbara	Goldsworthy Mining Ltd.	853,782.44	65.15	7,456,330.00
M.C. 878H, etc.	South-West	Western Mining Corporation	352,123.12	59.64	2,730,282.00
4 S.A.	West Pilbara	Hamersley Iron Pty. Ltd.	203,917.36	65.24	1,855,911.00
			1,551,168.92	63.97	13,088,234.09 (*b*)
		LEAD ORES AND CONCENTRATES (*g*) (*h*)		Lead Tons	
P.A. 285	Northampton	McKinnon, W. M.	(*i*) 8.42	4.83	932.00
M.L. 234	Northampton	Bridson, T. A.	(*i*) 197.16	158.46	32,684.00
Vic. Loc. 1472	Northampton	Mitchell, G. H.	(*i*) 46.52	29.65	5,011.21
M.C. 284	Northampton	Nooka Lead Mine	(*i*) 238.23	165.75	30,025.45
Vic. Loc. 436	Northampton	Hernesniemi, D.	(*i*) 66.40	41.79	7,987.60
Vic. Loc. 1146	Northampton	Camp and Party	(*i*) 34.69	22.34	4,294.58
Vic. Loc. 2932	Northampton	Camp and Party	(*i*) 14.24	9.79	1,931.21
M.C. 47	Northampton	Camp and Party	(*i*) 38.64	28.45	5,585.60
			644.30	460.96	88,451.65 (*b*)
		LEAD/ZINC ORES AND CONCENTRATES (*g*) (*h*)		Lead Content Tons	
M.C. 29	West Kimberley	Devonian Pty. Ltd.	*2,037.00	245.00	15,956.00 (*b*)
		* Silver content transferred to Silver Item	....	Zinc Content Tons 644.11	....
		*** LIMESTONE (For Building, and Burning Purposes, etc.)**			
M.C. 1080H	South-West	Bellombra, V.	160.00	....	400.00
M.C. 989H	South-West	Casella, S., Casella, M. and Ioppolo, G. J.	3,441.00	....	8,602.00
Swan Loc. 1370	South-West	Cooper, D. B.	1,227.95	....	4,052.26
M.C. 692H, etc.	South-West	Franconi, D. & S.	44.00	....	125.00
M.C. 1105H	South-West	Moore, F. W. & E. M.	1,717.00	....	3,434.00
M.C. 1093H	South-West	Multari, N.	5,146.00	....	15,942.00
M.C. 1071H	South-West	Koot, J. M.	22,917.00	....	23,269.00
M.C. 575H, etc.	South-West	Susac, F. & Y.	360.00	....	450.00
M.C. 874H	South-West	Brambles Holdings Ltd.	5,603.00	....	1,118.40
M.C. 723H	South-West	Plozza, C. W. & W. A.	80.00	....	160.00
Lot M 1405	South-West	Parham Grazing Company	7,968.75	....	19,922.38
Private Property	South-West	†Unspecified Producers	524,587.00	....	571,370.00
M.C. 727H	South-West	Thiess Bros. Pty. Ltd.	4,031.00	....	1,209.30
			577,282.70	....	650,054.34 (*c*)

* Incomplete. † From Private Property not held under the Mining Act.

TABLE V.—*Quantity and Value of Minerals, other than Gold, Reported during the Year 1966—continued*

Number of Lease, Claim or Area	Goldfield or Mineral Field	Registered Name of Producer	Quantity Long Tons	Metallic Content	Value $A
		* LIMESTONE (For Agricultural Purposes)			
M.C. 50	Dundas	Esperance Lime Supply	153.00	....	612.00 (c)
		* Incomplete.			
		LITHIUM ORES (Petalite) (h)		Li20 Units	
M.L. 80, etc.	Coolgardie	Australian Glass Manufacturers Co. Pty. Ltd.	933.00	3,918.60	14,124.00 (a)
		MAGNESITE			
M.C. 76, etc.	Phillips River	Magnesite (W.A.) Pty. Ltd.	135.07	....	1,958.52 (a) (b)
		MANGANESE (Metallurgical Grade) (g)		Av. Assay Mn%	
M.C. 268, etc.	Pilbara	Mt. Sydney Manganese Pty. Ltd.	53,510.12	50.94	1,270,334.60
M.C. 244L, etc.	Pilbara	Westralian Ores Pty. Ltd.	42,233.00	52.09	1,000,505.00
M.C. 30P, etc.	Peak Hill	Broken Hill Pty. Co. Ltd.....	21,222.82	46.51	456,786.65
M.C. 24P, etc.	Peak Hill	Westralian Ores Pty. Ltd.	19,682.00	37.88	318,684.00
			136,647.94	48.73	3,046,310.25 (b)
		MANGANESE (Low Grade)			
M.C. 24P, etc.	Peak Hill	Westralian Ores Pty. Ltd.	100.00	not known	1,599.00 (a)
		MINERAL BEACH SANDS (Ilmenite) (g)		Av. Assay Ti02%	
Sus. Loc. 7	South-West	Cable (1956) Ltd.	4,982.66	54.09	See Footnote
M.C. 746H	South-West	Ilmenite Minerals Pty. Ltd.	40,487.55	54.94	
D.C. 56H, etc.	South-West	Cable (1956) Ltd.	28,564.98	54.56	
D.C. 13H, etc.	South-West	Ilmenite Pty. Ltd.	6,787.00	52.85	
M.L. 398H, etc.	South-West	Western Mineral Sands Pty. Ltd.	130,131.00	53.74	
M.C. 619H, etc.	South-West	Westralian Oil Ltd.	85,685.00	58.75	
M.C. 516H, etc.	South-West	Western Titanium N.L.	174,257.93	54.63	
			470,896.12	55.13	4,621,179.34 (b)
		Footnote: Current Values for separate Companies not available for publication.			
		MINERAL BEACH SANDS (Monazite) (g) (h)		Th02 Units	
M.C. 619H, etc.	South-West	Westralian Oil Ltd.	613.00	3,964.70	69,731.00
M.C. 516H, etc.	South-West	Western Titanium N.L.	1,137.55	7,678.89	132,035.17
D.C. 56H, etc.	South-West	Cable (1956) Ltd.	96.87	629.65	12,903.20
M.C. 746H	South-West	Ilmenite Minerals Pty. Ltd.	47.20	302.18	6,608.00
			1,894.62	12,575.42	221,277.37 (b)
				Reo Units	
M.C. 746H	South-West	Ilmenite Minerals Pty. Ltd.		2,699.86	
		MINERAL BEACH SANDS (Rutile) (g) (h)		Ti02 Tons	
M.C. 516H, etc.	South-West	Western Titanium N.L.	576.38	552.90	40,515.12 (b)
		MINERAL BEACH SANDS (Leucoxene) (g) (h)		Ti02 Tons	
M.C. 619H, etc.	South-West	Westralian Oil Ltd.	206.00	138.02	5,124.00
M.C. 516H, etc.	South-West	Western Titanium N.L.	549.89	491.99	26,148.70
			755.89	630.01	31,272.70 (b)
		MINERAL BEACH SANDS (Zircon) (g) (h)		Zr02 Tons	
D.C. 56H, etc.	South-West	Cable (1956) Ltd.	728.96	477.46	33,765.90
M.C. 619H, etc.	South-West	Westralian Oil Ltd.	13,887.00	9,055.95	498,585.00
M.C. 516H, etc.	South-West	Western Titanium N.L.	10,297.37	6,783.03	250,106.07
M.C. 746H	South-West	Ilmenite Minerals Pty. Ltd.	1,584.20	1,033.43	68,954.51
			26,497.53	17,349.87	851,411.48 (b)
		OCHRE (Red)			
M.C. 26	Murchison	Universal Milling Co. Pty. Ltd.	207.00	....	4,140.00 (a)

TABLE V.—*Quantity and Value of Minerals, other than Gold, Reported during the Year 1966—continued*

Number of Lease, Claim or Area	Goldfield or Mineral Field	Registered Name of Producer	Quantity Long Tons	Metallic Content	Value $A
		PETALITE (See Lithium Ores)			
		PYRITES ORES AND CONCENTRATES (For Sulphur)		Sulphur Content Tons	
G.M.L. 5715E, etc.	East Coolgardie	Gold Mines of Kalgoorlie (Aust.) Ltd.	22,110.22	7,585.56	189,638.73
G.M.L. 1460, etc.	Dundas	Norseman Gold Mines N.L.	(i) (j) 54,026.00	25,611.95	833,432.00
			76,136.22	33,197.51	1,023,070.73 (a)
		SEMI PRECIOUS STONES (Beryl—coloured)	Lb.		
Crown Land	Murchison	Sundry Persons—Crown Land	200.00	....	100.00
		SEMI PRECIOUS STONES (Topaz—Blue)	Lb.		
Crown Land	Murchison	Sundry Persons—Crown Land	7.00	....	3.50
		SEMI PRECIOUS STONES (Chalcedony)	Lb.		
P.A. 5652H	Broad Arrow	W.A. Lapidary and Rock Hunting Club Inc.	448.00	....	400.00
		SILVER	Fine Oz.		
		By-Product Gold Mining	213,364.26	....	250,341.67
		By-Product Copper Mining	5,698.72	....	6,197.88
		By-Product Lead Mining	4,119.98	....	4,731.80
			223,182.96	....	261,271.35
		TALC			
Private Property	South-West	Three Springs Talc Pty. Ltd.	9,155.34	....	231,625.24 (b) (c)
		TANTO/COLUMBITE ORES AND CONCENTRATES (g) (h)		Ta205 Units	
M.C. 107, etc.	Pilbara	Wilson, L. J.	.91	57.49	5,208.75
M.C. 674	Pilbara	Denton, E. O. & S. C. M.	.05	1.73	113.97
M.L. 80, etc.	Coolgardie	Australian Glass Manuf. Co. Pty. Ltd.	.60	22.27	1,382.00
M.C. 27	Yalgoo	D. E. Gray and Party	1.58	99.77	6,581.82
P.A. 2640	Yalgoo	Phillips, E. R.	.13	6.87	605.83
M.L. 660, etc.	Greenbushes	Greenbushes Tin N.L.	(k) .99	50.73	5,038.00
M.C. 647, etc.	Greenbushes	Vultan Syndicate	(k) .45	15.53	761.07
			4.71	254.39	19,691.44 (b)
		TIN (g) (h)		Tons	
D.C. 53, etc.	Pilbara	Cooglegong Tin Pty. Ltd.	215.01	148.38	445,555.45
D.C. 201, etc.	Pilbara	Pilbara Tin Pty. Ltd.	41.57	27.27	84,307.27
D.C. 16, etc.	Pilbara	Leonard, H. V.	38.89	26.96	88,124.45
D.C. 254, etc.	Pilbara	J. A. Johnston & Sons Pty. Ltd.	99.83	71.47	217,745.37
D.C. 281, etc.	Pilbara	J. A. Johnston & Sons Pty. Ltd.	44.32	30.00	90,852.33
D.C. 276, etc.	Pilbara	D.D. Mining Co.	31.47	21.65	66,004.24
D.C. 305	Pilbara	Russell, H. H.	0.26	0.18	563.30
D.C. 535	Pilbara	Edwards, J. M. & M. A.	3.49	2.35	7,078.05
D.C. 258, etc.	Pilbara	Edwards, M. R.	37.60	24.96	72,841.25
Crown Lands	Pilbara	Sundry Persons-Crown Lands	2.91	2.10	6,250.06
Crown Lands	Pilbara	Sundry Persons—Crown Lands	22.05	15.54	45,847.00
Crown Lands	Pilbara	Crown Lands—District Generally	8.71	6.17	19,089.96
D.C. 691, etc.	Pilbara	Canning Tin Pty. Ltd.	3.78	2.34	6,504.28
Crown Lands	Pilbara	Sundry Persons—Crown Lands	1.83	1.32	3,549.00
M.C. 815	Pilbara	Edwards, M. (Brockman Tin)	1.91	1.28	3,566.99
D.C. 546	Pilbara	Edwards, R. L.	0.73	0.47	1,293.89
D.C. 276	Pilbara	Talga Gold Mining Syndicate (Edwards, R. W.)	3.24	2.21	6,155.62
D.C. 705	Pilbara	Edwards, R. W., Jeffrey, J. M., and Jones, D. V.	0.69	0.47	1,325.02
D.C. 497	Pilbara	Henderson, J. M.	4.86	3.37	10,067.00
D.C. 481	Pilbara	Stubbs, S. H.	0.38	0.25	712.85
P.A. 2750	Pilbara	Mallett, G. and Billing, A. J.	0.10	0.07	140.00
P.A. 3772	Murchison	Hronsky, M.	0.15	0.07	48.75
M.C. 94	Dundas	Blake, L. V. and Norton, B. P.	0.84	0.54	1,807.90
P.A. 2603	Dundas	Weston, B. T.	2.82	1.78	5,283.30
M.L. 647, etc.	Greenbushes	Vultan Syndicate	6.34	4.47	12,692.00
M.L. 660, etc.	Greenbushes	Greenbushes Tin N.L.	14.36	10.21	32,327.92
M.C. 63	Greenbushes	Austin, H. J.	0.87	0.57	1,836.30
			589.01	406.45	1,231,569.55 (b)
		TUNGSTEN ORES AND CONCENTRATES (Scheelite) (g) (h)		W03 Units	
P.A. 7765	Coolgardie	Short, P. L.	0.52	32.33	771.00 (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) Estimated Nominal Value ex Works. (g) Only results of shipments finalised during the period under review. (h) Metallic content calculated on assay basis. (i) Concentrates. (j) By-Product Gold Mining. (k) By-Product Tin Mining. (l) Crude Ore only.

TABLE VI—TOTAL MINERAL OUTPUT OF WESTERN AUSTRALIA

Recorded mineral production of the State to 31st December, 1966, showing for each mineral the progressive quantity produced and value thereof, as reported to the Department of Mines ; including Gold (Mint and Export) as from 1886, and Other Minerals as from commencement of such records in 1899.

Mineral		Quantity	Value
			$A
Abrasive Silica Stone	tons	1.50	18.00
Alumina (From Bauxite)	,,	509,344.00	(*f*)30,560,640.00
Alunite (Crude Potash)	,,	9,073.05	431,729.44
Antimony Concentrates (*a*)	,,	9,829.69	484,994.00
Arsenic (*a*)	,,	38,674.08	1,494,410.00
Asbestos—			
Anthophyllite	,,	509.35	13,547.42
Chrysotile	,,	11,018.68	980,118.00
Crocidolite	,,	152,466.74	33,496,644.98
Tremolite	,,	1.00	50.00
Barytes	,,	5,599.16	71,784.40
Bauxite (Crude Ore)	,,	36,741.00	187,069.50
Beryl	,,	3,632.04	940,203.33
Bismuth	lb.	12,479.70	7,628.60
Building Stone (*g*)—			
Chrysotile—Serpentine	tons	4.45	106.00
Granite (Facing Stone)	,,	338.00	15,440.00
Lepidolite	,,	8.35	146.00
Prase	,,	9.50	275.00
Quartz (Dead White)	,,	360.00	5,840.00
Quartzite	,,	1,280.00	5,120.00
Sandstone	,,	541.00	3,246.00
Sandstone (Donnybrook)	,,	83.00	3,486.00
Slate	,,	235.00	2,115.00
Spongolite	,,	2,432.00	22,138.00
Calcite	,,	5.00	50.00
Chromite	,,	14,419.05	416,593.50
Clays—			
Bentonite	,,	11,534.63	73,580.92
Brick, Pipe and Tile Clays (*g*)	,,	354,433.00	611,089.90
Cement Clays	,,	332,244.05	535,936.12
Fireclay	,,	443,746.36	849,159.41
Fullers Earth	,,	459.40	3,821.00
White Clay—			
Ball Clay	,,	24,203.60	149,068.60
Kaolin	,,	5,630.62	19,958.54
Coal	,,	35,906,144.34	111,653,976.90
Copper Ore and Concentrates	,,	292,432.75	7,546,336.00
Copper (Metallic By-Product) (*a*)	,,	(*i*) 191.50	65,375.10
Corundum	,,	63.15	1,310.00
Cupreous Ore and Concentrates (Fertiliser)	,,	83,494.16	2,946,224.10
Diamonds (*e*)	Carats	....	48.00
Diatomaceous Earth (Calcined)	tons	471.50	14,276.50
Dolomite	,,	3,046.82	26,118.20
Emeralds (cut and rough)	carats	18,381.68	3,844.00
Emery	tons	21.15	750.00
Felspar	,,	69,056.61	501,068.18
Fergusonite	,,	.30	782.80
Gadolinite	,,	1.00	224.00
Glass Sand	,,	154,237.51	(*g*) 196,803.12
Glauconite	,,	(*h*) 6,467.00	(*f*) 300,769.00
Gold (Mint and Export)	fine ozs.	66,167,755.16	1,029,452,197.00
Graphite	tons	153.20	2,608.40
Gypsum	,,	954,154.53	2,029,369.68
Iron Ore—			
Pig Iron Recovered	,,	495,034.08	(*f*)21,626,801.12
Ore Exported	,,	16,369,088.92	42,469,486.38
For Flux	,,	58,064.35	74,096.00
Jarosite	,,	9.54	75.00
Kyanite	,,	4,215.69	43,562.00
Lead Ores and Concentrates	,,	478,912.81	10,255,035.89
Limestone (*g*)	,,	1,358,514.21	1,584,933.84
Lithium Ores—			
Petalite	,,	2,108.98	31,917.20
Spodumene	,,	106.58	3,627.20
Magnesite	,,	27,160.80	287,837.40
Manganese—			
Metallurgical Grade	,,	899,758.25	22,444,605.37
Battery Grade	,,	2,218.25	90,860.20
Low Grade	,,	5,054.36	81,538.20
Mica	lb.	32,930.00	7,968.48
Mineral Beach Sands—			
Ilmenite Concentrates	tons	1,976,284.44	18,923,993.3[illegible]
Monazite Concentrates	,,	7,635.48	662,748.6[illegible]
Rutile Concentrates	,,	4,578.86	256,052.2[illegible]
Leucoxene Concentrates	,,	3 760.08	129,133
Zircon Concentrates	,,	97,942.93	2,476,668.2[illegible]
Crude Concentrates (Mixed)	,,	155.95	1,553.0[illegible]

TABLE VI.—Total Mineral Output of Western Australia—*continued*

Mineral		Quantity	Value A$
Ochre—			
Red	tons	9,587.94	204,950.40
Yellow	„	447.60	5,955.50
Phosphatic Guano	„	11,857.06	145,420.90
Pyrites Ore and Concentrates (For Sulphur) (*b*)	„	1,222,067.62	14,599,297.09
Quartz Grit	„	829.50	1,400.70
Semi-Precious Stones—			
Beryl (Coloured)	lb.	200.00	100.00
Chalcedony	„	896.00	800.00
Chrysoprase	„	5.00	10.00
Opaline	„	25.00	7.50
Prase	„	2,240.00	80.00
Tiger Eye Opal	„	120.00	194.00
Topaz (Blue)	„	7.00	3.50
Sillimanite	tons	2.00	26.00
Silver (*c*)	fine ozs.	11,427,289.67	5,518,235.51
Soapstone	tons	565.40	3,855.70
Talc	„	67,433.82	1,826,424.60
Tanto-Columbite Ores and Concentrates	„	561.07	1,180,731.00
Tin	„	22,630.10	11,411,857.55
Tungsten Ore and Concentrates—			
Scheelite	„	167.88	140,566.24
Wolfram	„	303.42	123,517.30
Vermiculite	„	1,832.96	23,661.20
Zinc (Metallic By-Product) (*d*)	„	2,887.75	(*d*)
Zinc Ore (Fertiliser)	„	20.00	200.00
Total Value to 31st December, 1966		....	1,382,767,876.28

(*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. Value included in Lead Value.
(*e*) Quantity not recorded.
(*f*) Value of mineral or concentrate recovered.
(*g*) Incomplete.
(*h*) Mineral Recovered.
(*i*) Assayed Metallic Content.

Footnote.—Comprehensive mineral production records maintained in the Statistical Branch of the Department of Mines show locality, producers, period, quantity, assayed or metallic content, and value of the various minerals listed above.

TABLE VII.

SHOWING AVERAGE NUMBER OF MEN EMPLOYED ABOVE AND UNDER GROUND IN THE LARGER GOLDMINING COMPANIES OPERATING IN WESTERN AUSTRALIA DURING THE YEARS FROM 1957 TO 1966 INCLUSIVE.‡

COMPANY	1957			1958			1959			1960			1961			1962			1963			1964			1965			1966		
	Above	Under	Total	Above	Under	Total	Above	Under	Total	Above	Under	Total	Above	Under	Total	Above	Under	Total	Above	Under	Total	Above	Under	Total	Above	Under	Total	Above	Under	Total
†Boulder Perseverance, Ltd.	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Central Norseman Gold Corporation N.L.	165	226	391	166	232	398	173	214	387	169	209	378	163	220	383	151	213	364	151	208	359	157	181	338	156	148	304	144	152	296
Eclipse Gold Mines N.L.	....	....	....	27	8	35	17	10	27	17	15	32	18	13	31	16	9	25	13	6	19	2	4	6	....	....	....	....	....	....
Golden Horseshoe (New) Ltd.	6	....	6	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Gold Mines of Kalgoorlie (Aust.) Ltd. (Boulder)	417	500	917	392	538	930	374	455	829	375	446	821	374	430	804	379	436	815	426	449	875	378	379	757	355	363	718	365	343	708
Great Boulder G.Ms. Ltd.	330	400	730	323	387	710	308	399	707	290	385	675	296	385	681	300	369	669	307	378	685	306	381	687	291	360	651	262	351	613
*Great Western Consolidated	220	223	443	220	241	461	207	218	425	197	174	371	164	124	288	144	92	236	58	28	86	16	....	16	7	....	7	6	....	6
Hill 50 Gold Mine N.L.	108	94	202	103	103	206	95	88	183	97	87	184	97	93	190	99	110	209	98	130	228	100	143	243	91	113	204	88	102	190
†Kalgoorlie Enterprise Ltd.	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
§Kalgurli Ore Treatment Co. Ltd.	33	....	33	28	....	28	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....			
Lake View and Star Ltd.	460	517	977	433	525	958	451	535	986	432	513	945	417	514	931	411	527	938	417	545	962	393	520	913	370	483	853	353	477	830
Moonlight Wiluna Gold Mines Ltd. (Timoni)	36	31	67	35	31	66	31	27	58	31	24	55	30	30	60	33	39	72	35	38	73	35	31	66	32	36	68	31	31	62
Gold Mines of Kalgoorlie (Aust.) Ltd. (Mt. Charlotte)	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	8	51	59	8	67	75	7	95	102
North Kalgurli (1912) Ltd.	158	250	408	163	263	426	181	251	432	181	249	430	187	246	433	208	243	451	212	249	461	214	254	468	203	260	463	203	259	462
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)	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)....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Radio Gold Mines	7	7	14	6	6	12	6	6	12	6	6	12	6	5	11	5	5	10	6	5	11	7	5	12	4	4	8	3	1	4
†South Kalgurli Consolidated	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Sons of Gwalia Ltd.	107	146	253	109	142	251	99	137	236	106	139	245	103	143	246	96	137	233	98	119	217	9	....	9	3	....	3	....	....	....
Sunshine Reward Amalgamated Leases	2	....	2	8	3	11	5	2	7	3	1	4	2	2	4	2	2	4	2	2	4	2	2	4	1	1	2	....	....	....
All other Operators	498	349	847	476	313	789	521	398	919	469	290	759	509	283	792	524	321	845	520	341	861	513	292	835	482	256	738	516	264	780
State Average (inc. Diggers)	2,581	2,804	5,385	2,512	2,840	5,352	2,493	2,780	5,273	2,406	2,586	4,992	2,404	2,541	4,945	2,411	2,552	4,963	2,374	2,527	4,901	2,140	2,243	4,383	2,003	2,091	4,094	1,978	2,075	4,053

* 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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