ANNUAL REPORT 1968

THE DEPARTMENT OF MINES, WESTERN AUSTRALIA

PRESENTED TO BOTH HOUSES BY HIS EXCELLENCY'S COMMAND

REPORT OF THE DEPARTMENT *of* MINES WESTERN AUSTRALIA FOR THE YEAR 1968

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To 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 1968, together with reports from the officers controlling Sub-Departments, and Comparative Tables furnishing statistics relative to the Mining Industry.

I. R. BERRY,
Under Secretary for Mines.

Perth, 1969.

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WESTERN AUSTRALIA

Report of the Department of Mines for the Year 1968

DIVISION I

PART 1—GENERAL REMARKS

The Honourable Minister for Mines:

I have the honour to submit for your information a report on the Mining Industry for the year 1968.

The estimated value of the mineral output of the State (including gold, coal and petroleum) for the year was $205,203,737, an increase of $56,573,290 compared with that for the preceding year and constitutes an all-time record. This is 38.06% higher than the previous figure set in 1967.

To the end of 1968 the progressive value of the whole mineral production of the State amounted to $1,736,603,312 of which gold accounted for $1,064,309,844 (see Table IV at back).

Minerals other than gold and coal rose in value to $183,601,289 an increase of $57,807,268 above that for 1967 to establish a new all-time record 45.95% higher than the previous figure set in 1967. This increase was due mainly to the continued expansion of iron ore production and to a lesser extent to the increased production of nickel and petroleum.

The continuing increase in production was reflected in royalty revenue and during the year royalty totalling $8,827,700 was collected as against $5,164,464 in 1967, $721,954 in 1966 and $450,155 in 1965.

IRON ORE

Exported and locally used iron ore continued its rapid increase from 9,979,459 tons valued at $67,522,532 in 1967 to 17,178,025 tons valued at $120,740,604 in 1968 and held its position as the State's leading mineral, a position it attained in 1967 by supplanting gold which had held that distinction for 75 years.

Hamersley Iron Pty. Ltd. was the major producer for the year with 8.1 million tons of Mt. Tom Price iron ore valued at $70.1 million.

Goldsworthy Mining Ltd. was second with 4.4 million tons exported from the Mt. Goldsworthy deposit and valued at $37.1 million f.o.b. Port Hedland.

Dampier Mining Co. Ltd. continued production of iron ore from Cockatoo and Koolan Islands and reported 2,778,271 tons valued at $5,997,493 of which 91,412 tons were shipped to Japan and the remainder to B.H.P. steelworks in the Eastern States. This company continued production of Koolyanobbing iron ore and reported 1,231,194 tons (valued at $2.4 million) railed to Kwinana. Of this, 670,000 were shipped to New South Wales Steelworks.

Western Mining Corporation reported production from Koolanooka of 634,092 tons of iron ore valued at $5,094,193 f.o.b. Geraldton.

Construction work for the Mt. Newman iron ore project continued throughout the year with exports to commence in April, 1969.

PETROLEUM

(Crude Oil)

Production of oil from Barrow Island during 1968 amounted to 10,641,703 barrels valued at a little over $34 million.

The two year task of drilling 246 development wells to develop the Windalia reservoir on the Island was completed during the year and a waterflood programme was initiated to prolong the life of the field and increase total oil recovery from this reservoir which is now expected to ultimately yield 200 million barrels.

Two offshore rigs—the jack-up drilling barge "Jubilee" and the floating rig "Glomar Tasman"—began operations off the Western Australian coast during the year. "Jubilee" drilled Quinns Rock No. 1 about 22 miles N.N.W. of Fremantle without encountering hydrocarbons, but oil flows of up to 1,014 barrels a day were obtained in tests of Legendre No. 1 well drilled by the "Glomar Tasman" 120 miles N.E. of Barrow Island. Both rigs are continuing to drill in W A. waters.

General oil exploration both offshore and onshore continued throughout the year and further gas was found near Dongarra in Mondarra No. 1 well from which a gas flow of 10 million cubic feet a day was obtained through a ⅜ inch surface choke.

GOLD

The estimated value of gold received at the Perth Branch of the Royal Mint plus that exported in gold-bearing material was $16,785,723, a decline of $1,286,201 when compared with the figure for 1967 and equalled only 8.18% of the value of all minerals for 1968.

The quantity of gold advised as being received at the Perth Branch of the Royal Mint (510,784.17 fine ounces) together with that contained in gold-bearing material exported for treatment (918.86 fine ounces) totalled 511,703.03 fine ounces which was 64,317.98 fine ounces less than for the previous year (see Table 1 (b) Part 2).

Details of gold production for the year reported directly to the Department as distinct from that received at the Mint are set out in Table 1 at back. The total tonnage of gold ore treated was 2,307,737 being 223,888 tons less than for 1967.

The famous "Golden Mile" locality of Kalgoorlie-Boulder mining centres in the East Coolgardie Goldfield has to date treated a total of 93.2 million tons of ore for 37.3 million fine ounces of gold valued at a progressively estimated $603.74 million. These figures represent 58.25% of the State's reported ore tonnage and gold production.

West Australian gold included in sales on overseas premium markets by the Gold Producers' Association Ltd. for the period July, 1967, to June, 1968, totalled 554,519 fine ounces. The premium received in excess of the Mint value amounted to $794,964, an overall average of 143.39 cents per fine ounce as compared with an average of 17.424 cents per fine ounce for the period October, 1966, to June, 1967. The higher premium reflects the higher prices of gold ruling on the free market during the period. That premium, less expenses, was distributed to the producer members during 1968 and approximated 140.59 cents per fine ounce.

Subsidy payments made by the Commonwealth Government during the year under the Gold Mining Industry Assistance Act totalled $2,621,049, a decrease of $976,091 compared with the previous year. This decrease not only reflects the decreasing production, but also the higher premium obtained on the free market, part of which reduces the amount of subsidy payable. Of the subsidy paid $2,556,522 went to large producers and $64,527 to small producers.

Since the peak post-war production of nearly 900,000 fine ounces in 1957, the annual output of gold has decreased by some 385,000 fine ounces to the present figure of just over 500,000 fine ounces in 1968.

This decline represents a loss in value to the State of $11,000,000 a year and reflects the serious plight of the gold mining industry, caused mainly by constantly rising costs which are not offset by corresponding increases in the price of gold.

Subsidy payments by the Commonwealth have also not been sufficient to offset rising costs and gold production in W.A. will continue to decline unless there is a substantial rise in the price or the subsidy.

COAL

Coal production from Collie during the year showed an increase of 25,228 tons over that for 1967 and the overall average value per ton fell by 5.6 cents.

Figures for the last three years were:

	1966	1967	1968
Tons	1,061,095	1,062,151	1,087,379
Total Value	$4,562,087	$4,764,503	$4,816,725
Average value per ton	$4·2994	$4·4857	$4·4297
Average effective workers....	726	694	649
Proportion of deep mined coal	46·48%	46·54%	44·35%

ALUMINA
(from Bauxite)

Western Aluminium N.L. again increased production of Alumina. A further stage in the expansion of the Kwinana Alumina Refinery was completed during the year with the coming into operation of third unit of the plant. The refinery now has a capacity of 610,000 tons of alumina per annum, and at the end of the year construction of a fourth unit, to raise capacity to 817,000 tons, was proceeding.

Mining of bauxite near Jarrahdale was being progressively lifted by Western Aluminium to meet its increasing alumina production, and other companies were investigating further bauxite deposits in the Darling Range.

Negotiations for development of the Mitchell Plateau bauxite were proceeding with a view to establishing an industry in the Admiralty Gulf area of the Kimberleys.

NICKEL

At Kambalda, Western Mining Corporation Ltd. treated 191,026 tons of nickel ore during the year and reported export of 45,273 tons of concentrates which contained nickel having an estimated nominal value of a little over $10.1 million. Site preparation and road forming for the Kwinana nickel refinery commenced in August, and at the end of the year construction of the refinery was well under way.

During the year Great Boulder Gold Mines Limited and North Kalgurli (1912) Ltd. proceeded with development of the known ore body in the Scotia area towards ultimate ore production and mining and concentration of nickel ore was expected to commence in August, 1969.

During the year the search for nickel was continued with increasing intensity in many areas throughout the State and promising deposits had been located in the Higginsville-Widgiemooltha area and at Nepean south of Coolgardie.

OTHER MINERALS

Other minerals to yield over a million dollars for the year were ilmenite—$4,559,736, manganese —$3,083,140, tin concentrates—$2,309,788, while pig iron valued at $3,189,393 was recovered by the Wundowie Charcoal Iron & Steel Industry from Koolyanobbing Iron Ore.

Talc production from Three Springs increased sharply from 7,901 tons valued at $227,037 in 1967 to 24,724 tons worth $467,706 in 1968. Tanto/columbite ores and concentrates also showed an increase from 23 tons valued at $131,680 in 1967 to 493 tons valued at $365,504, an increase in value of $233,824 over the previous year.

Production of pyrite by Norseman Gold Mines N.L. ceased in June, 1968 and the value of sulphur used for acid manufacture fell by $646,861 compared with the previous year. Closure of the mine was due to the discontinuance of the use of pyrite for sulphuric acid manufacture by the superphosphate manufacturers.

Exploration for minerals of all kinds was pursued with unabated vigour throughout 1968 and with the prospect of new discoveries together with expansion of existing mines, the continued growth of the state's mining industry seems assured.

PART 2—COMPARATIVE STATISTICS

TABLE 1

SUMMARY

Mineral Production : Quantity, Value, Persons Engaged

	1967	1968	Variation
IRON ORE—			
Reported to Department—			
Tons	10,033,788	17,270,425	+ 7,236,637
Value ($A)	$70,592,465	$123,929,997	+ $53,337,532
Persons Engaged	1,185	1,295	+ 110
PETROLEUM— CRUDE OIL—			
Reported to Department—			
Barrels	4,646,938	10,641,703	+ 5,994,765
†Value ($A)	$14,853,605	$34,015,442	+ $19,161,837
Persons Engaged—			
Effective Workers (excluding absentees)	229	185	— 44
GOLD—			
Reported to Department (Mine Production)—			
Ore Tons	2,531,625	2,307,737	— 223,888
Gold (fine ounces)	573,445	515,639	— 57,806
Average Grade (dwts. per ton)	4·530	4·468	— ·062
Persons Engaged—			
(a) Effective Workers (excluding absentees)	4,027	3,567	— 460
(b) Total Pay Roll	4,362	3,869	— 493
Mint and Export (Realised Production)—			
Gold (fine ounces)	576,021	511,703	— 64,318
Estimated Value ($A) (including Overseas Gold Sales Premium)	$18,071,924	$16,785,723	— $1,286,201
COAL—			
Reported to Department (Mine Production)—			
Tons	1,062,151	1,087,379	+ 25,228
Value ($A)	$4,764,503	$4,816,725	+ $52,222
Persons Engaged—			
Effective Workers (excluding absentees)	694	649	— 45
OTHER MINERALS—			
Reported to Department—			
Value ($A)	$40,347,950	*$25,655,850	— $14,692,100
Persons Engaged—			
Effective Workers (excluding absentees)	1,715	1,994	+ 279
TOTAL ALL MINERALS—			
Value ($A)	$148,630,447	$205,203,737	+ $56,573,290
Persons Engaged—			
Effective Workers	7,850	7,690	— 160

* All-time record.

† Based on the price of $US3.58 ($A3.196428) per bbl. assessed by the Tariff Board for Barrow Island crude oil at Kwinana

TABLE 1 (*a*)

Quantity and Value of Minerals, other than Gold and Silver, produced during Years 1967 *and* 1968

Western Australia

Minerals	1967		1968		Increase or Decrease for Year Compared with 1967	
	Quantity	Value	Quantity	Value	Quantity	Value
	Tons	$A	Tons	$A	Tons	$A
Alumina (from Bauxite)	405,225·00	24,313,500	N.A.	N.A.	....	....
Asbestos (Chrysotile)	76·30	3,215	67·00	2,814	— 9·30	— 401
Barytes	962·25	21,613	655·66	9,968	— 306·59	— 11,645
Bauxite	....	....	1,607,988·10	N.A.	....	....
Beryl	10·97	3,682	13·40	5,668	+ 2·43	+ 1,986
Building Stone (Granite-Facing Stone)	6·00	48	....	....	— 6·00	— 48
(Quartzite)	1,318·00	5,464	1,318·00	5,260	....	— 204
(Quartz)	207·23	4,455	36·00	838	— 171·23	— 3,617
(Quartz—Dead White)	382·00	7,742	395·23	8,936	+ 13·23	+ 1,194
(Sandstone)	42·00	252	17·00	102	— 25.00	— 150
(Spongolite)	633·00	8,229	185·00	2,257	— 448.00	— 5,972
(Tripolite)	....	....	260·00	260	+ 260.00	+ 260
Clays (Bentonite)	112.00	896	37·70	302	— 74.30	— 594
(Cement Clay)	16,814·00	36,400	22,605·38	52,021	+ 5,791.38	+ 15,621
(Fireclay)	86,032·45	87,910	103,999·35	81,125	+ 17,966·90	— 6,785
(Kaolin)	332·45	2,164	....	....	— 332·45	— 2,164
(White Clay-Ball Clay)	739·00	5,812	949·00	7,592	+ 210.00	+ 1,780
(Brick, Pipe and Tile Clay)	82,289·00	115,050	46,190·70	99,224	— 36,098·30	— 15,826
Coal	1,062,150·80	4,764,503	1,087,379·05	4,816,725	+ 25,228·25	+ 52,222
Cobalt (Metallic By-Product Nickel Mining)	....	....	91·37	N.A.	+ 91.37	N.A.
Copper (Metallic By-Product Nickel Mining)	....	....	730·21	N.A.	+ 730.21	N.A.
Copper Ore and Concentrates	3,093·00	552,032	4,275·58	900,452	+ 1,182·58	+ 348,420
Cupreous Ore and Concentrates	776·13	52,108	689·83	51,231	— 86·30	— 877
Diatomaceous Earth (Calcined)	5·00	352	43·50	1,362	+ 38·50	+ 1,010
Felspar	342·00	5,112	469·00	7,035	+ 127·00	+ 1,923
Glass Sand	41,768·10	*19,909	20,560·00	*18,547	— 21,208·10	— 1,362
Gypsum	40,078·00	77,489	105,019·37	305,765	+ 64,941.37	+ 228,276
Iron Ore (Pig Iron Recovered)	54,328·00	3,069,933	57,888·00	3,189,393	+ 3,560·00	+ 119,460
(Exported)	9,979,459·87	67,522,532	16,250,231·35	110,989,634	+6,270,771·48	+ 43,467,102
(Pellets)	....	....	927,793·31	9,750,970	+ 927,793·31	+ 9,750,970
Lead Ores and Concentrates	909·68	96,893	417·63	39,985	— 492·05	— 56,908
Limestone*	746,777·50	802,084	964,099·45	924,511	+ 217,321·95	+ 122,427
Lithium Ores (Petalite)	667·00	10,477	738·00	11,731	+ 71·00	+ 1,254
Magnesite	1,258·48	12,224	166·36	2,412	— 1,092·12	— 9,812
Manganese (Metallurgical and Low Grades)	189,095·98	3,927,059	145,456·06	3,083,140	— 43,639·92	— 843,919
Mineral Beach Sands (Ilmenite)	429,620·24	4,185,150	464,386·83	4,559,736	+ 34,766·59	+ 374,586
(Monazite)	1,417·20	178,338	1,835·31	244,903	+ 418·11	+ 66,565
(Rutile)	400·00	28,758	845·43	66,754	+ 445·43	+ 37,996
(Leucoxene)	598·26	30,348	1,695·41	80,106	+ 1,097·15	+ 49,758
(Zircon)	29,618·18	1,147,908	28,372·07	899,378	— 1,246·11	— 248,530
(Xenotime)	....	....	2·00	4,946	+ 2·00	+ 4,946
Nickel Concentrates	2,252·92	381,628	45,272·82	10,128,936	+ 43,019·90	+ 9,747,308
Ochre (Red)	261·00	5,220	515·05	9,823	+ 254·05	+ 4,603
	bbls		bbls		bbls	
Petroleum—Crude Oil	4,646,938·00	14,853,605	10,641,703·00	34,015,442	+5,994,765·00	+ 19,161,837
	Tons		Tons		Tons	
Pyrites Ore and Concentrates (For Sulphur)	78,684·89	1,067,686	32,879·40	420,825	— 45,805·49	— 646,861
			Carats		Carats	
Semi Precious Stones			418·00	798	+ 418·00	+ 798
	lbs.		lbs.		lbs.	
	62,871·50	8,042	33,174·00	9,778	— 29,697·50	+ 1,731
	Tons		Tons		Tons	
Talc	7,901·24	227,037	24,724·07	467,706	+ 16,822·83	+ 240,669
Tanto/Columbite Ores and Concentrates	22·75	131,680	493·32	365,504	+ 470·57	+ 233,824
Tin Concentrates	1,238·71	2,358,771	1,562·78	2,309,788	+ 324·07	— 48,983
Tungsten Ores and Concentrates—(Scheelite)	1·30	2,858	....	....	— 1·30	— 2,858
(Wolfram)	·93	1,689	·61	603	— ·32	— 1,086
Total	....	$A130,137,857	....	$A187,954,281	....	+$A82,129,924

TABLE 1 (*b*)

Quantity and Value of Gold and Silver Exported and Minted during Years 1967 *and* 1968

Minerals	1967		1968		Increase or Decrease for Year Compared with 1967	
	Quantity	Value	Quantity	Value	Quantity	Value
	Fine Oz.	$A	Fine Oz.	$A	Fine Oz.	$A
Gold (Exported and Minted)	576,021·01	‡18,071,924	511,703·03	‡16,785,723	— 64,317·98	— 1,286,201
Silver (Exported and Minted)	309,476·12	420,666	227,653·16	463,733	— 81,822·96	+ 43,067
Total	....	$A18,492,590	....	$A17,249,456	....	—$A1,243,134
Grand Total	....	$A148,630,447	....	$A205,203,737	....	+$80,886,790

* Incomplete. ‡ Including Overseas Gold Sales Premium.

TABLE 2
ROYALTIES

Mineral	Royalty Collected		Increase or Decrease Compared with 1967
	1967	**1968**	
	$	**$**	$
Amethyst	25.40	**35.99**	+ 10.59
Asbestos	236.90	**10.06**	— 226.84
Barytes	74.40	**25.64**	— 48.76
Bauxite	99,463.11	**107,755.26**	+ 8,292.15
Bentonite	8.10	**1.90**	— 6.20
Beryl	1.97	**2.69**	+ .72
Building Stones	278.10	**233.00**	— 45.10
Chalcedony	7.75	**3.00**	— 4.75
Clays	4,965.45	**5,985.09**	+ 1,019.64
Coal	28,218.04	**25,599.31**	— 2,618.73
Cobalt	....	**461.68**	+ 461.68
Diatomaceous Earth (calcined)	1.35	**6.65**	+ 5.30
Emeralds	....	**4.00**	+ 4.00
Felspar	18.20	**18.90**	+ .70
Glass Sand	2,050.22	**917.30**	— 1,132.92
Gypsum	2,273.85	**2,332.13**	+ 58.28
Ilmenite Concentrates	47,773.46	**39,490.99**	— 8,282.47
Iron Ore	4,446,564.43	**7,174,278.27**	+2,727,713.84
Leucoxene Concentrates	60.40	**53.92**	— 6.48
Limestone	5,704.05	**12,420.83**	+ 6,716.78
Magnesite	111.52	**100.56**	— 10.96
Manganese	26,628.75	**23,616.14**	— 3,012.61
Monazite Concentrates	1,003.90	**965.95**	— 37.95
Nickel Concentrates	5,146.02	**148,317.35**	+ 143,171.33
Ochre	23.40	**25.76**	+ 2.36
Oil (Crude)	478,826.15	**1,270,827.89**	+ 792,001.74
Petalite	70.40	**71.20**	+ .80
Pyrites	8,012.90	**3,546.60**	— 4,466.30
Rutile Concentrates	52.50	**61.50**	+ 9.00
Scheelite	14.30	**3.98**	— 10.32
Talc	4,717.37	**6,478.53**	+ 1,761.16
Tanto/Columbite	696.09	**1,047.49**	+ 351.40
Tin Concentrates	248.86	**238.77**	— 10.09
Wolfram	6.39	**....**	— 6.39
Zinc Concentrates	129.00	**....**	— 129.00
Zircon Concentrates	3,051.15	**2,737.47**	— 313.68
Xenotime	....	**24.73**	+ 24.73
	5,166,463.88	**8,827,700.53**	+3,661,236.65

TABLE 3

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

Goldfield	Reported Yield		Percentage for each Goldfield		‡ Average Yield per ton of ore treated	
	1967	**1968**	1967	**1968**	1967*	**1968***
	Fine Oz.	Fine Oz.	Per cent.	Per cent.	Dwts.	Dwts.
1. Kimberley	6	....	·001	....	....	....
2. West Kimberley	....	....	....	....	....	....
3. Pilbara	1,351	**1,369**	·236	**.265**	18·531	**15·522**
4. West Pilbara	....	....	....	....	....	....
5. Ashburton	....	....	....	....	....	....
6. Gascoyne	714	**741**	·124	**·144**	21·636	**22·395**
7. Peak Hill	10	**10**	·001	**·002**	....	....
8. East Murchison	1,138	**391**	·198	**·076**	8·527	**8·058**
9. Murchison	41,632	**32,951**	7·257	**6·386**	5·134	**5·095**
10. Yalgoo	135	**221**	·024	**·043**	3·566	**5·807**
11. Mt. Margaret	1,183	**1,282**	·206	**·248**	22·093	**16·712**
12. North Coolgardie	3,121	**417**	·544	**·081**	7·572	**4·048**
13. Broad Arrow	903	**901**	·157	**·175**	11·414	**17·296**
14. North-East Coolgardie	450	**465**	·078	**·090**	10·720	**3·768**
15. East Coolgardie	432,145	**389,572**	75·319	**75·506**	4·000	**3·928**
16. Coolgardie	1,811	**1,199**	·316	**·232**	6·523	**4·461**
17. Yilgarn	1,360	**1,118**	·237	**·217**	15·364	**12·514**
18. Dundas	86,523	**84,095**	15·080	**16·299**	9·342	**9·483**
19. Phillips River†	1,199	**1,218**	·209	**·236**	....	**50·752**
20. South-West Mineral Field	35	....	·006	....	26·923	....
21. State Generally	39	....	·007	....	....	....
	573,755	**515,950**	100·000	**100·000**	4·541	**4·469**

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

TABLE 4

Output of Gold from the Commonwealth of Australia during 1968

State	Output of Gold	Value*†	Percentage of Total
	Fine oz.	$A	%
Western Australia	511,703	15,990,759	66·11
Queensland	77,900	2,434,375	10·07
Northern Territory	131,564	4,111,390	17·00
Tasmania	33,526	1,047,687	4·33
Victoria....	10,792	337,250	1·39
New South Wales	8,453	264,156	1.09
South Australia	38	1,187	·01
Total	773,976	24,186,804	100.00

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

TABLE 5

Total Coal output from Collie River Mineral Field, 1967 *and* 1968, *estimated Value therefrom, Average Number of Men Employed and Output per Man.*

Year	Total Output	Estimated Value	Men Employed			Output per Man Employed		
			Above Ground	Under Ground	Open Cuts	In Open Cuts	Under Ground	Above and Under Ground
Deep Mining—	Tons	$A	No.	No.	No.	Tons	Tons	Tons
1967	494,281	2,915,567	99	410	....	....	1,206	971
1968	482,219	2,843,540	91	378	....	....	1,276	1,028
Open Cut Mining—								
1967	567,870	1,848,936	....	....	185	3,070	....	....
1968	605,160	1,973,185	....	....	180	3,362	....	....
Totals—								In All Mines
1967	1,062,151	4,764,503	99	410	185	....	....	1,530
1968	1,087,379	4,816,725	91	378	180	....	....	1,675

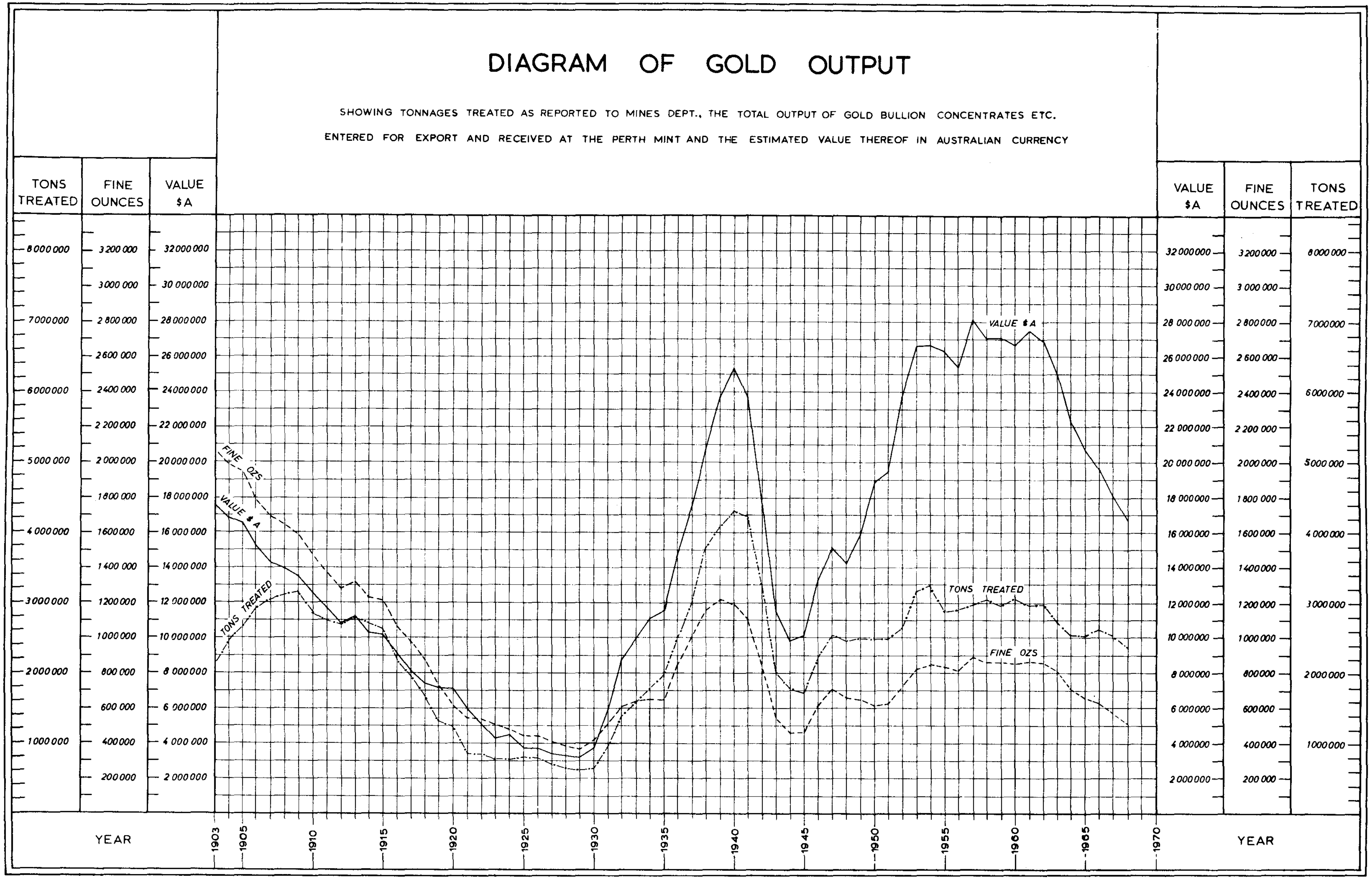
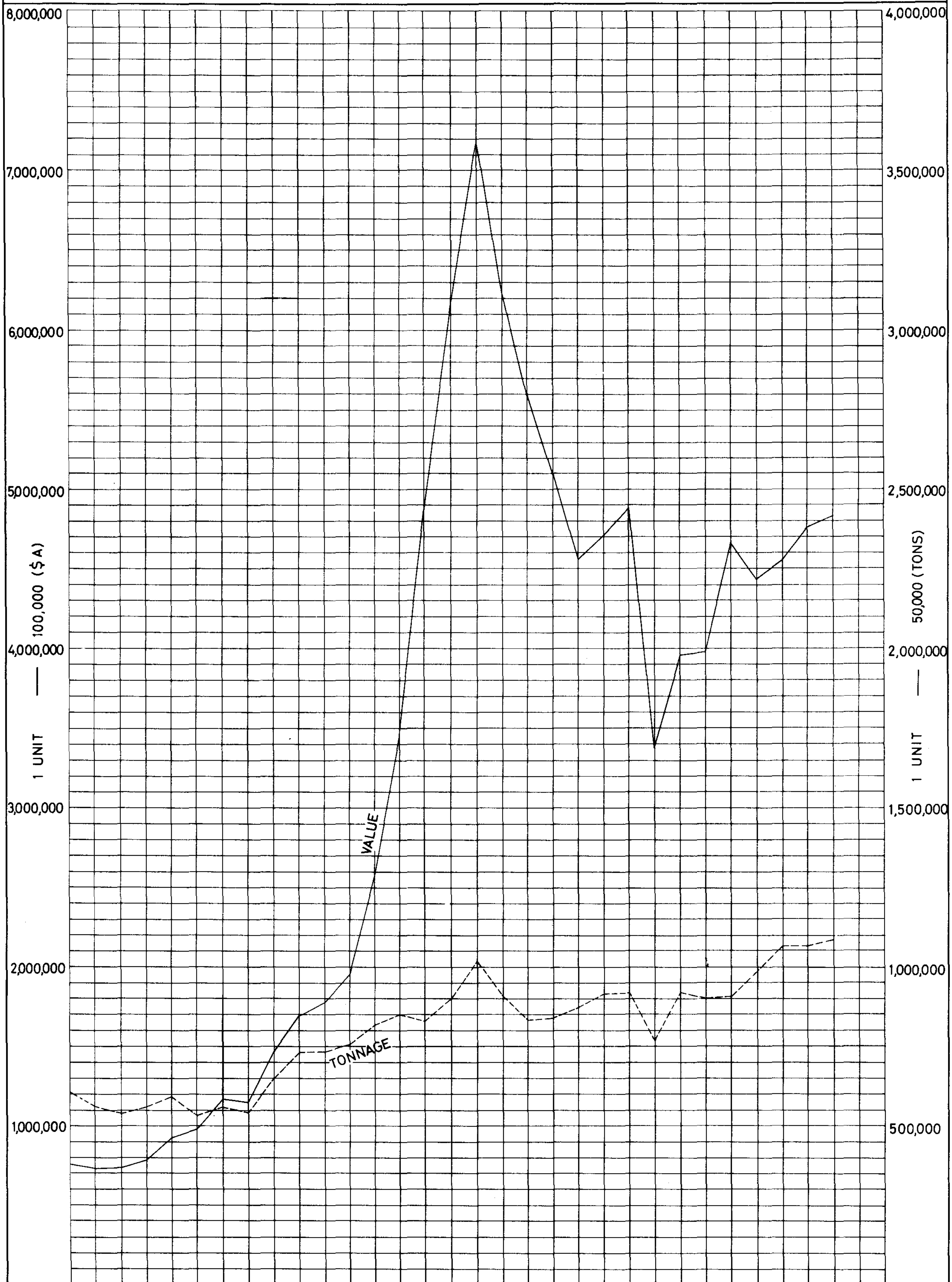


DIAGRAM OF GOLD OUTPUT
SHOWING TONNAGES TREATED AS REPORTED TO MINES DEPT., THE TOTAL OUTPUT OF GOLD BULLION CONCENTRATES ETC.
ENTERED FOR EXPORT AND RECEIVED AT THE PERTH MINT AND THE ESTIMATED VALUE THEREOF IN AUSTRALIAN CURRENCY
TONS TREATED
FINE OUNCES
VALUE $A
VALUE $A
TONS TREATED
FINE OZS
YEAR

GRAPH OF COAL OUTPUT

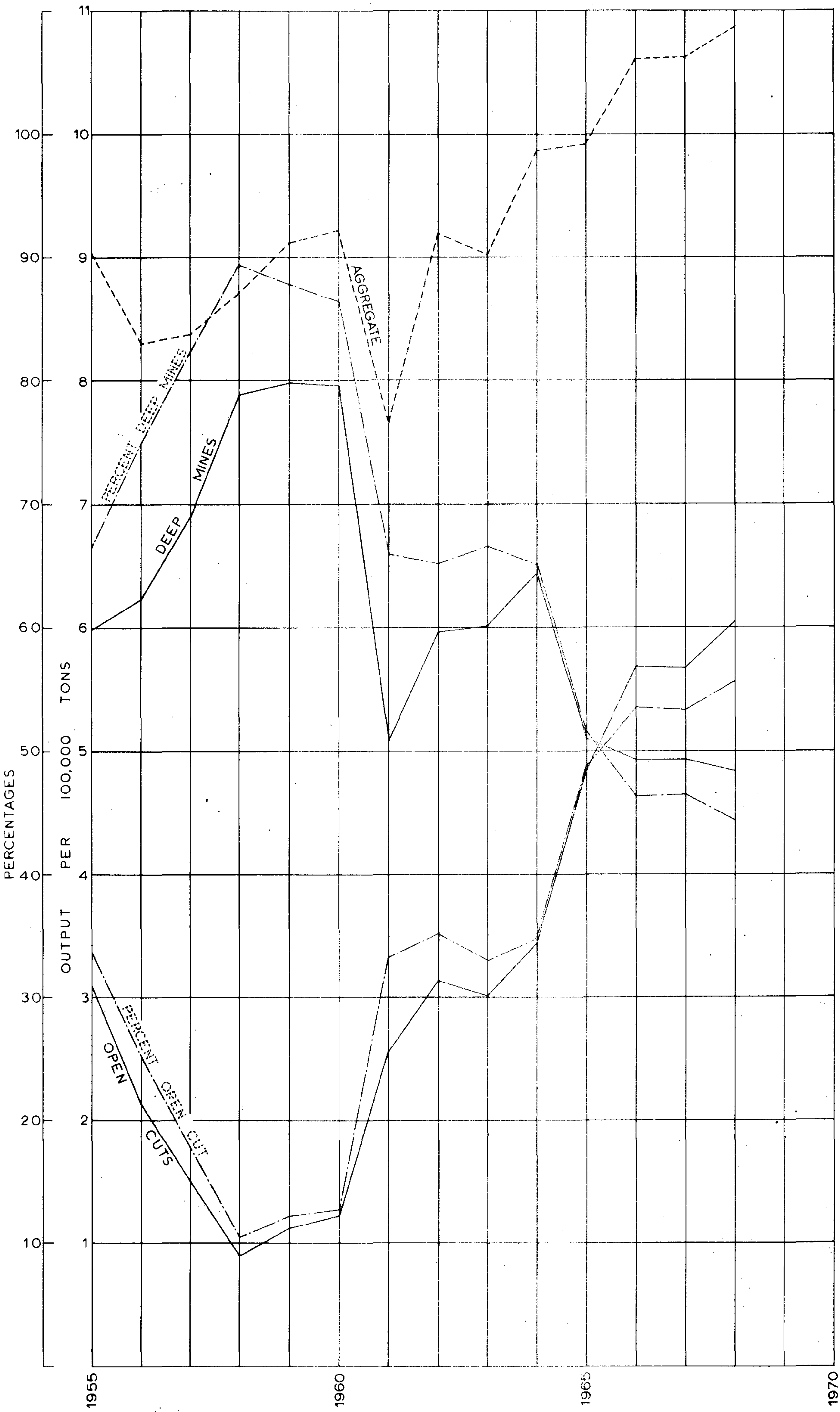
SHOWING QUANTITIES AND VALUES AS REPORTED TO MINES DEPARTMENT



YEAR	VALUE $A	TONS
1938	750,176	604,793
1939	725,622	557,535
1940	729,000	539,427
1941	778,556	556,574
1942	922,990	581,176
1943	979,442	531,546
1944	1,166,150	558,322
1945	1,145,792	543,363
1946	1,460,208	642,287
1947	1,680,498	730,506
1948	1,760,472	732,938
1949	1,944,490	750,594
1950	2,575,498	814,351
1951	3,433,576	848,475
1952	4,914,592	830,461
1953	6,146,146	886,182
1954	7,177,636	1,018,343
1955	6,264,148	903,792
1956	5,595,012	830,008
1957	5,105,310	838,660
1958	4,560,398	870,882
1959	4,713,064	917,434
1960	4,878,390	922,393
1961	3,260,518	765,740
1962	3,961,556	919,112
1963	3,970,120	902,495
1964	4,678,934	987,420
1965	4,409,972	993,741
1966	4,562,087	1,061,095
1967	4,765,503	1,062,151
1968	4,816,725	1,087,379

GRAPH OF TREND IN COAL OUTPUT

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



LEASES AND OTHER HOLDINGS UNDER VARIOUS ACTS RELATING TO MINING.

TABLE 6

MINING ACT 1904.

Mining Tenements applied for during 1968 *and in force at* 31*st December*, 1968 (*Compared with* 1967).

—	Applied for				In Force			
	1967		1968		1967		1968	
	No.	Acres	No.	Acres	No.	Acres	No.	Acres
Gold—								
Gold Mining Leases	105	2,031	**307**	**6,392**	1,030	19,278	**1,032**	**19,299**
Dredging Claims	2	600	**3**	**900**	5	939	**5**	**943**
Prospecting Areas	404	7,298	**441**	**8,280**	344	6,240	**307**	**5,766**
Temporary Reserves	35	130,220	....	....	439	129,130	**272**	**78,546**
Totals	546	140,149	**751**	**15,572**	1,818	155,587	**1,616**	**104,554**
Coal—								
Coal Mining Leases	10	2,880	**14**	**4,165**	51	15,011	**50**	**14,496**
Prospecting Areas	8	9,300	**2**	**3,436**	....	....	....	....
Temporary Reserves	7	816,800	**5**	**319,200**	11	1,164,320	**2**	**124,800**
Totals	25	828,980	**21**	**326,801**	62	1,179,331	**52**	**139,296**
Other Minerals—								
Mineral Leases	46	8,164	**65**	**13,768**	240	30,884	**260**	**34,841**
Dredging Claims	70	11,258	**21**	**1,660**	416	34,894	**419**	**34,451**
Mineral Claims	2,803	763,763	**7,230**	**1,982,820**	1,735	222,728	**2,947**	**552,270**
Prospecting Areas	158	3,224	**162**	**3,384**	120	2,425	**142**	**3,021**
Temporary Reserves	533	55,101,910	**468**	**179,572,998**	423	68,569,043	**518**	**67,769,075**
Totals	3,610	55,888,319	**7,946**	**181,574,630**	2,934	68,859,974	**4,286**	**68,393,658**
Other Holdings—								
Miner's Homestead Leases	5	975	**10**	**623**	344	34,109	**342**	**34,326**
Miscellaneous Leases	4	84	**8**	**138**	111	1,684	**114**	**1,763**
Residential Areas	1	1	....	....	63	52	**63**	**63**
Business Areas	....	....	**1**	**1**	24	20	**24**	**24**
Machinery Areas	1	5	....	....	27	77	**26**	**72**
Tailings Areas	1	2	....	....	24	94	**24**	**94**
Garden Areas	8	35	**6**	**21**	67	213	**67**	**218**
Quarrying Areas	25	463	**16**	**325**	23	360	**22**	**335**
Water Rights	9	26	**2**	**5,124**	143	3,165	**145**	**3,135**
Licenses to Treat Tailings	38	....	**28**	....	36	....	**19**	....
Totals	92	1,591	**71**	**6,232**	862	39,774	**846**	**40,030**
Grand Totals	4,273	56,859,039	**8,789**	**181,923,235**	5,676	70,234,666	**6,800**	**68,677,538**

TABLE 6 (a)

SPECIAL ACTS

Leases applied for during 1968 *and in force at* 31*st December*, 1968 (*Compared with* 1967)

Mineral	Applied for				In Force			
	1967		1968		1967		1968	
	No.	Acres	No.	Acres	No.	Acres	No.	Acres
Bauxite	....	....	....	....	7	3,137,280	**7**	**3,137,280**
Iron	2	384,000	....	....	4	419,106	**4**	**419,106**
Salt	....	....	....	....	....	....	**1**	**51,980**
Totals	2	384,000	....	....	11	3,556,386	**12**	**3,608,366**

TABLE 6 (b)

PETROLEUM ACTS

Permits, Licenses and Leases applied for during 1968 *and in force at* 31*st December*, 1968 (*Compared with* 1967)

Holding	Applied for				In Force			
	1967		1968		1967		1968	
	No.	Acres	No.	Acres	No.	Acres	No.	Acres
Onshore—								
Petroleum Act, 1936–1966 :								
Permits to Explore	6	43,468,800	**4**	**16,551,680**	37	417,617,920	**30**	**170,667,520**
Licences to Prospect	15	1,662,720	**30**	**2,882,029**	74	8,360,960	**55**	**4,217,740**
Petroleum Leases	....	....	....	....	2	128,000	**2**	**128,000**
Totals	21	45,131,520	**34**	**19,433,709**	113	426,106,880	**87**	**175,013,260**
Offshore—								
Petroleum (Submerged Lands) Act, 1967:								
Exploration Permits	....	....	**41**	**366,483,200**	....	....	**11**	**142,611,200**
Production Licences	....	....	....	....	....	....	....	....
Totals	....	....	**41**	**366,483,200**	....	....	**11**	**142,611,200**
Grand Totals	21	45,131,520	**75**	**385,916,909**	113	426,106,880	**98**	**317,624,460**

TABLE 6 (c)

MINING ACT, 1904

Leases in Force at 31*st December*, 1968 *in each Goldfield, Mineral Field or District*

Goldfield, Mineral Field, or District	Gold Mining Leases		Mineral Leases		Miner's Homestead Leases		Miscellaneous Leases	
	No.	Acres	No.	Acres	No.	Acres	No.	Acres
Ashburton	....	....	7	136	....	....	1	5
Black Range	4	53	....	....	....	....	....	....
Broad Arrow	27	402	3	568	....	....	1	5
Bulong	4	72	....	....	....	....	1	3
Collie	....	....	49	14,491	....	....	....	....
(Private Property)	....	....	2	520	....	....	....	....
Coolgardie	62	1,140	70	16,474	22	1,859	6	60
Cue	2	24	....	....	6	1,233	....	....
Day Dawn	17	342	....	....	1	20	....	....
Dundas	312	6,901	....	....	19	935	....	....
East Coolgardie	307	5,453	....	....	66	3,329	62	1,168
Gascoyne	7	147	1	8	....	....	....	....
Greenbushes	....	....	68	9,463	11	588	....	....
Kanowna	3	51	....	....	12	702	....	....
Kimberley	2	34	....	....	....	....	....	....
Kunanalling	2	47	....	....	2	520	....	....
Kurnalpi	3	72	....	....	....	....	....	....
Lawlers	21	404	....	....	5	1,110	....	....
Marble Bar	55	785	4	89	2	10	9	125
Meekatharra	8	152	1	10	11	1,866	1	1
Menzies	20	367	....	....	7	740	1	10
Mount Magnet	59	900	4	38	1	10	....	....
Mount Malcolm	9	197	....	....	9	1,270	....	....
Mount Margaret	3	64	....	....	7	58	....	....
Mount Morgans	5	105	1	30	....	....	....	....
Niagara	2	29	....	....	1	20	....	....
Northampton	....	....	9	171	1	53	....	....
(Private Property)	....	....	2	33	....	....	....	....
Nullagine	14	256	....	....	2	22	3	50
Peak Hill	1	8	16	545	5	250	2	20
Phillips River	3	29	13	563	105	14,604	....	....
(Private Property)	....	....	....	....	....	....	....	....
South-West	1	24	4	903	....	....	1	2
(Private Property)	....	....	8	1,903	....	....	....	....
Ularring	10	141	....	....	1	20	....	....
West Kimberley	....	....	23	755	....	....	5	75
West Pilbara	4	68	9	102	2	11	8	171
Wiluna	....	....	5	382	17	4,148	3	11
Yalgoo	6	91	2	33	1	10	....	....
Yerilla	19	362	6	1,800	1	10	....	....
Yilgarn	37	543	3	120	25	928	10	57
(Private Property)	3	36	....	....	....	....	....	....
Outside Proclaimed	....	....	2	200	....	....	....	....
Totals	1,032	19,299	312	49,337	342	34,326	114	1,763

Gold Mining Leases on Crown Land	1,029	19,263 acres
Gold Mining Leases on Private Property	3	36 acres
Miner's Homestead Leases on Crown Land	342	34,326 acres
Mineral Leases on Crown Land	300	46,896 acres
Mineral Leases on Private Property	12	2,456 acres
Other Leases on Crown Land	114	1,743 acres

TABLE 6 (d)
MINING ACT, 1904

Claims and Authorised Holdings in Force at 31st December, 1968 in each Goldfield, Mineral Field or District.

Goldfield, Mineral Field or District	Prospecting Areas		Dredging Claims		Mineral Claims		Residence Areas		Business Areas		Machinery Areas		Tailings Areas		Garden Areas		Water Rights		Quarrying Areas	
	Number	Acres	Number	Acres	Number	Acres	Number	Acres	Number	Acres	Number	Acres	Number	Acres	Number	Acres	Number	Acres	Number	Acres
Ashburton	9	215	1	5	36	6,128	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Black Range	3	72	....	....	25	7,184	4	4	....	....	....	....	....	....	....	....	....	....	....	....
Broad Arrow	29	532	....	....	125	35,323	1	1	1	1	....	....	....	....	....	....	3	8	....	....
Bulong	5	92	....	....	21	4,995	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Collie	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Coolgardie	55	937	....	....	314	88,596	4	4	....	....	1	1	....	....	2	6	5	17	....	....
Cue	17	264	....	....	11	236	4	4	....	....	....	....	....	....	....	....	1	3	....	....
Day Dawn	1	24	....	....	1	120	....	....	....	....	....	....	....	....	4	20	....	....	....	....
Dundas	12	276	....	....	78	10,339	....	....	....	....	....	....	1	5	....	....	2	12	....	....
East Coolgardie	29	451	....	....	262	73,071	32	32	....	....	1	2	12	56	7	31	11	32	4	42
Gascoyne	8	191	....	....	37	3,659	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Greenbushes	....	....	....	....	8	485	1	1	....	....	....	....	....	....	9	37	2	31	....	....
Kanowna	19	386	....	....	53	15,624	....	....	....	....	....	....	....	....	2	7	1	1	....	....
Kimberley	5	52	....	....	18	3,607	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Kunanalling	10	172	....	....	39	11,158	....	....	....	....	....	....	....	....	....	....	3	25	....	....
Kurnalpi	8	168	....	....	74	21,616	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Lawlers	9	204	....	....	8	667	....	....	....	....	2	6	1	5	....	....	1	1	....	....
Marble Bar	33	690	395	31,550	430	54,610	2	2	5	5	7	21	2	10	7	20	41	1,331	10	170
Meekatharra	13	264	....	....	19	4,709	....	....	....	....	....	....	....	....	....	....	2	5	....	....
Menzies	4	45	....	....	66	16,801	....	....	....	....	1	1	....	....	3	9	5	13	....	....
Mount Magnet	23	472	....	....	8	1,294	....	....	....	....	....	....	....	....	12	15	3	6	....	....
Mount Malcolm	8	171	....	....	19	5,447	....	....	....	....	....	....	....	....	7	29	10	164	....	....
Mount Margaret	1	24	....	....	25	7,500	....	....	....	....	....	....	....	....	....	....	4	4	....	....
Mount Morgans	6	120	....	....	13	3,859	....	....	....	....	....	....	....	....	....	....	2	6	....	....
Niagara	6	127	....	....	11	3,300	....	....	....	....	....	....	....	....	....	....	3	6	....	....
Northampton	6	110	....	....	18	2,785	....	....	....	....	....	....	....	....	....	....	1	9	....	....
Private Property	....	....	....	....	1	10	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Nullagine	11	204	8	1,632	334	20,387	....	....	....	....	3	7	3	4	3	6	15	48	....	....
Peak Hill	13	280	....	....	79	11,864	1	1	....	....	2	8	....	....	....	....	....	....	....	....
Phillips River	4	74	....	....	46	5,001	....	....	....	....	1	2	1	2	....	....	....	....	1	5
Private Property	....	....	....	....	3	424	....	....	....	....	....	....	....	....	....	....	....	....	....	....
South-West	4	69	10	1,778	174	15,816	....	....	....	....	....	....	....	....	....	....	2	7	....	....
Private Property	....	....	4	341	164	23,045	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Ularring	8	180	....	....	....	....	....	....	....	....	1	1	2	4	....	....	7	8	....	....
West Kimberley	1	12	....	....	5	384	....	....	....	....	2	10	....	....	....	....	1	12	3	30
West Pilbara	16	361	6	88	236	47,129	4	4	11	11	....	....	....	....	4	19	9	39	....	....
Wiluna	1	24	....	....	13	3,900	....	....	....	....	1	1	1	3	1	5	5	1,325	....	....
Yalgoo	34	788	....	....	42	9,996	....	....	6	6	1	5	1	5	....	....	1	10	....	....
Yerilla	6	135	....	....	72	21,004	....	....	....	....	....	....	....	....	....	....	5	12	....	....
Yilgarn	29	541	....	....	57	10,029	10	10	1	1	3	7	....	....	6	14	....	....	4	88
Private Property	3	60	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Outside Proclaimed	....	....	....	....	2	168	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Totals	449	8,787	424	35,394	2,947	552,270	63	63	24	24	26	72	24	94	67	218	145	3,135	22	335

TABLE 7

MEN EMPLOYED

Average number of Men reported as engaged in Mining during 1967 *and* 1968

Goldfield	District	Gold 1967	Gold 1968	Other Minerals 1967	Other Minerals 1968	Total 1967	Total 1968
Kimberley	....	....	....	....	....	....	....
West Kimberley	....	....	....	439	379	439	379
Pilbara	Marble Bar	31	32	392	491	423	523
	Nullagine	10	10	2	2	12	12
West Pilbara	....	1	....	518	420	519	420
Ashburton	....	....	....	229	187	229	187
Gascoyne	....	4	5	....	1	4	6
Peak Hill	....	1	1	22	18	23	19
East Murchison	Lawlers	48	14	2	....	50	14
	Wiluna	5	3	....	....	5	3
	Black Range	7	5	....	....	7	5
Murchison	Cue	18	12	5	3	23	15
	Meekatharra	7	6	2	2	9	8
	Day Dawn	4	2	1	....	5	2
	Mt. Magnet	219	202	....	....	219	202
Yalgoo	....	3	5	3	4	6	9
Mt. Margaret	Mt. Morgans	10	3	....	....	10	3
	Mt. Malcolm	34	17	....	....	34	17
	Mt. Margaret	18	5	....	....	18	5
North Coolgardie	Menzies	55	41	....	....	55	41
	Ularring	29	31	....	....	29	31
	Niagara	9	7	....	....	9	7
	Yerilla	9	9	....	....	9	9
Broad Arrow	....	93	96	....	....	93	96
North-East Coolgardie	Kanowna	23	25	....	....	23	25
	Kurnalpi	25	27	....	....	25	27
East Coolgardie	East Coolgardie	2,752	2,429	2	....	2,754	2,429
	Bulong	17	17	....	....	17	17
Coolgardie	Coolgardie	155	143	196	409	351	552
	Kunanalling	27	23	3	1	30	24
Yilgarn	....	124	124	16	97	140	221
Dundas	....	289	273	114	44	403	317
Phillips River	....	....	....	95	111	95	111
South-West Mineral Field	....	....	....	1,006	1,233	1,006	1,233
Northampton Mineral Field	....	....	....	18	22	18	22
Greenbushes Mineral Field	....	....	....	60	50	60	50
Outside Proclaimed Goldfield	....	....	....	4	....	4	....
Collie Coalfield	....	....	....	694	649	694	649
Total—All Minerals	....	4,027	3,567	3,823	4,123	7,850	7,690

	1967	1968
Minerals Other than Gold—		
Alumina (from Bauxite)	526	724
Asbestos	2	....
Barytes	4	2
Beryl	2	3
Building Stone	11	11
Clays	21	21
Coal	694	649
Copper	97	111
Cupreous Ore (Fertiliser)	38	17
Felspar	7	5
Glass Sand	5	10
Gypsum	17	12
Iron Ore	1,185	1,295
Lead	20	22
Limestone	15	27
Magnesite	1	....
Manganese	24	23
Mineral Beach Sands (Ilmenite, etc.)	331	340
Nickel	189	403
Petroleum—Crude Oil	229	185
Pyrites	111	40
Semi-precious Stones	....	5
Talc	7	11
Tanto/Columbite	12	....
Tin	275	207
Total, Other Minerals	3,823	4,123

PART 3—STATE AID TO MINING.

(a) State Batteries

At the end of the year there were 19 State Batteries including the Northampton Base Metal Plant.

From inception to the end of 1968, gold, silver, tin, tungsten, lead, copper and tantalite ores to the value of $39,874,859 have been treated at the State Batteries. Included in the above amount is $15,644,325 gold premium and $108,800 premium paid by sales of gold by the Gold Producers Association Ltd. $38,298,234 came from 3,579,469½ tons of gold ore, $299,751 from 83,885¼ tons of tin ore, $38,896 from 3,971¾ tons tungsten ore, $1,192,278 from 50,598¾ tons lead ore, $11,932 from 220½ tons of copper ore and $30,981 from 263½ tons of tantalite ore, and silver valued at $2,787 recovered as a By-Product from the cyaniding of Gold Tailings.

During the year 22,074¼ tons of gold ores were crushed for 9,415 ozs. bullion, estimated to contain 7,979 ozs. fine gold equal to 7 dwts. 5 grs. per ton. The average value of sands after amalgamation was 2 dwts. 16 grns. per ton, making the average head value 9 dwts. 21 grs. per ton. Cyanide plants produced 2,490 ozs. fine gold, giving a total estimated production for the year of 10,469 ozs. fine gold valued at $339,727.

The working expenditure for the year for all plants was $477,410 and the revenue was $80,725 giving a working loss of $396,685 which does not include depreciation or interest. Since the inception of State Batteries, the Capital expenditure has been $1,790,820 made up of $1,431,595 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 $69,786 compared with $66,247 for 1967.

The working expenditure from inception to the end of 1968 exceeds revenue by $5,666,446.

(b) Prospecting Scheme

At the end of the year 36 men were in receipt of prospecting assistance as compared with 38 at the end of 1967.

Total expenditure for 1968 was $27,048 and refunds amounted to $3,350.

Assisted prospectors crushed 1,026 tons of ore during the year for 288 ozs. of gold.

Progressive total figures since the inception of the scheme are:

Expenditure—$984,160.

Refunds—$189,819.

Ore Crushed—124,100 tons.

Gold won—57,463 ozs.

The rate of assistance remained at $17.50 per man per week in the more remote localities and $15 per man per week in the less isolated areas.

(c) Geological Survey of Western Australia

The continued high tempo of mineral exploration throughout the State maintained the great demand for the services and assistance of the Geological Survey, particularly in providing regional geology, specialists' services and information from the Survey's library, records and open files.

The scope of the advice and information available from the Branch is well known and in addition to providing assistance to the mining industry, the Survey continued to help agricultural and pastoral development and industry generally, particularly in relation to both surface and underground water supplies and again assisted the general public with advice and information.

PART 4—SCHOOL OF MINES.

(a) *Kalgoorlie*

Enrolments at the School increased from 278 in 1967 to 297 in 1968 and this was reflected in the School revenue which totalled $15,114 compared with $14,756 for the previous year.

In 1968 the first two years of the new Associateship courses were taught and the new Senior Certificate Course became effective.

The Chamber of Mines agreed to grant Day Release to School of Mines students in 1968 and this materially assisted in accelerating the development of students in courses.

The School provided the usual services to industry and the general public and gold and mineral samples submitted for assay and determination totalled 520.

The Government's decision to link the W.A. School of Mines with the Western Australian Institute of Technology was implemented and after 67 years under the control of the Mines Department, administration of the School was passed to the Institute at the end of 1968.

(b) *Norseman*

Enrolments at Norseman declined from 50 in 1967 to 46 in 1968 of which only nine were for tertiary subjects while the remainder were for technician courses.

Arrangements were made for the Norseman School to be taken over by the Technical Education Division of the Education Department and at the end of the academic year it ceased to be a branch of the School of Mines.

PART 5—INSPECTION OF MACHINERY.

During the year the work of this Branch increased greatly due to the phenomenal growth of multi-storey building and industrial expansion with its large construction projects.

Boiler registrations rose by 652 to a total of 10,747 in 1968 as compared with the previous year, and machinery groups registered increased from 56,569 in 1967 to 61,111 in 1968. The latter figures include 990 lifts in operation as compared with 867 at the end of 1967.

Inspectors carried out 7,337 boiler inspections and 37,587 machinery inspections during the year as compared with 6,990 and 34,641 respectively in 1967.

The Board of Examiners granted Certificates of Competency to 157 Engine Drivers, 467 Crane Drivers and 135 Boiler Attendants. This is an overall increase of approximately 25% on figures for 1967.

PART 6—GOVERNMENT CHEMICAL LABORATORIES.

The Laboratories continued to maintain close association with other Government Departments and to serve both State and Commonwealth Authorities as well as the general public.

The number of samples submitted to the Laboratories for analysis, determination and investigation in 1968 was 19,986, a small decrease as compared with 20,570 submitted in 1967. This respite from the rapid increase in recent years enabled the Laboratories to reduce the backlog of samples from 4,057 at the end of 1967 to 2,514 at the end of 1968.

At 31st December, 1968, the staff of the Laboratories numbered 116 being only one more than at the end of the previous year. However, staff changes (staff "turnover") in 1968 totalled 25—more than twice those of any previous year and tended to interrupt the free flow of work and so reduce output.

The diverse functions and wide range of subjects dealt with by the Laboratories are shown in detail in Division VII of this Report.

PART 7—EXPLOSIVES BRANCH.

This Branch continued to carry out its fundamental function of ensuring that the quality of explosives and their transport and storage complied with State requirements.

The quantity of explosives, including ammonium nitrate, used in the State reached an all-time record in 1968, and the graph in Division VIII shows the increase since 1962.

Among the many licenses issued by the Branch during the year was one License to Manufacture Explosives issued to a factory near Port Hedland. This is the first time in Western Australia that a mining explosive has been blended and packaged in a licensed factory, the product being a gelatinised mixture of ammonium nitrate, water and combustibles which is used for large scale open-cut mining.

In December 1968 the Branch moved from the Treasury Building to new accommodation in Albert House, 10 Victoria Avenue, Perth. The new offices provided greatly improved facilities for the expanding functions of the Branch, and good progress was reported in preparation for a system of licensing under the Flammable Liquids Regulations due to operate from 1st November, 1969.

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

Examination of mine workers for detection of silicosis, asbestosis and tuberculosis continued at the Kalgoorlie State X-Ray Laboratory, the Perth Chest Clinic and through the Mobile X-Ray Unit which visited three goldfields and the principal leases on the East Coolgardie Goldfield.

A total of 7,748 examinations were made of which 3,870 were re-examinations under the Mine Workers Relief Act and 3,878 examinations under the Mines Regulation Act. Of the latter, 3,476 were new applicants and 402 re-examinees.

Compensation payments under the old Miners Phthisis Act continued to decrease and totalled $12,425 to 56 beneficiaries as compared with $13,571 to 60 beneficiaries in 1967.

PART 9—SURVEYS AND MAPPING BRANCH.

Formerly known as the Survey Examination and Drafting Branch, the name of this office was changed during the year to Surveys and Mapping Branch as being more in keeping with its functions.

Surveys of mining tenements continued at a high level with a total of 539 completed at a cost of $97,902 compared with 465 at a cost of $64,980 in 1967.

This Branch continued to provide maps and technical plans for the public, the Geological Survey and other branches of the Department, and also charted a record number of 6,015 applications for mining tenements in addition to 467 Temporary Reserves and 70 applications for oil tenements.

PART 10—STAFF.

The year again brought many problems and pressure of work and I am glad to record my appreciation of the efforts of staff members both in Perth and on the goldfields in continuing to cope with these boom-time conditions as far as possible.

In this summary I have mentioned only main items of the Department's various activities and detailed reports of Branches are contained in Divisions II to X hereunder.

I. R. BERRY,
Under Secretary for Mines.

Mines Department,
Perth.

DIVISION II

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Report of the State Mining Engineer for the Year 1968

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Under Secretary for Mines:

I submit the Annual Report for the State Mining Engineer's Branch which is mainly comprised of the following sections:—

Mineral and Metal Production—by J. K. N. Lloyd—Assistant State Mining Engineer.

Mines Inspection and Accident Statistics—by J. Boyland—Mining Engineer-Senior Inspector of Mines.

Petroleum Exploration and Production—by A. J. Sharp—Petroleum Engineer.

Drilling Operations—by D. A. Macpherson—Drilling Engineer.

Board of Examiners—by W. J. Cahill—Secretary Board of Examiners.

MINERALS, METAL AND OIL

For 1968 iron ore production provided the most outstanding increase reaching 17,178,024 tons compared with 9,979,459 tons for the previous year.

Bauxite production was higher at 1,607,988 tons and nickel concentrates from Kambalda reached 45,272 tons—containing 12 per cent. nickel—for the Company's first full year of production.

Gold production for the year at 515,950 ozs. represented a decline of 57,804 ozs. on the previous year. The calculated value—$16,903,058—included $779,619 distributed by the Gold Producers Association from the sale of 554,519 fine ozs. at an average premium of 143.39 cents per oz.

Oil production from Barrow Island reached 10,782,681 barrels of crude oil for the Company's first full year of production—compared with 4,646.938 barrels for last year.

DRILLING

During the year the Drilling Section's Store and Workshops were removed from Welshpool into new premises in Harris Street, Carlisle.

In operations most of the footage drilled was for water exploration in the Agaton, Gnangara, Cue and Albany areas. However, special drilling required for design purposes was carried out for the Ord River Dam project and for the investigation to provide Bunbury with a deeper Harbour. In addition diamond drilling was carried out at Northam and Woolgangie as part of the Upper Mantle Investigation conducted by the Australian National University.

STAFF

Appointments

Petroleum Engineer—A. J. Sharp; 26/9/68.

Drilling Engineer—D. A. Macpherson; 18/3/68.

Mining Engineer/District Inspector of Mines—George Munro; 22/2/68.

Promotions

Mining Engineer/District Inspector of Mines—I. W. Loxton; 8/1/68. From Special Inspector of Mines.

There were no other staff changes during the year.

A. Y. WILSON,
State Mining Engineer.

MINERAL AND METAL PRODUCTION

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

Mineral production for the year 1968 is described in this report which is based on information supplied by the Statistician and Inspectors of Mines. Statistics relating to the mining industry are tabulated as follows:—

Table "1"—Mineral Output

Table "2"—Development Footages

Table "3"—Principal Gold Producers

TABLE 1

Mineral Output

Mineral	1967		1968	
	Tons	Value	Tons	Value
		$A		$A
Asbestos—Chrysotile	76·30	3,215	67·00	2,814
Barite	962·25	21,613	655·66	9,968
Bauxite—Alumina	1,354,041·20	24,313,500	1,607,988·10	*
Bentonite	112·00	896	37·70	302
Beryl	10·97	3,682	13·40	5,668
Building Stone	2,588·23	26,190	2,211·23	17,653
Clays	186,206·90	247,335	173,744·43	239,962
Coal	1,062,150·80	4,764,503	1,087,379·05	4,816,725
Cobalt	....	....	91·37	*
Copper—				
Ore and Concentrates	3,093·00	552,032	4,275·58	900,452
Fertilizer Grade	776·13	52,108	689·83	51,231
Metal	....	....	730·21	*
Diatomaceous Earth	5·00	353	43·50	1,362
Felspar	342·00	5,112	469·00	7,035
Glass Sand	41,768·10	19,909	20,560·00	18,547
Gold (fine ounces)	573,754·67	17,997,131	515,950·05	16,903,058
Gypsum	40,078·00	77,489	105,019·37	305,765
Ilmenite	429,620·24	4,185,150	464,386·83	4,559,736
Iron Ore	9,979,459·87	67,522,532	17,178,024·66	120,740,604
Iron Ore—Pig Iron	86,401·00	3,069,933	92,400·00	3,189,393
Lead Ore and Concentrates	909·68	96,893	417·63	39,985
Leucoxene	598·26	30,348	1,695·41	80,106
Limestone	746,777·50	802,084	964,099·45	924,511
Lithium Ore—Petalite	667·00	10,477	738·00	11,731
Magnesite	1,258·48	12,224	166·36	2,412
Manganese	189,095·98	3,927,059	145,456·06	3,083,140
Monazite	1,417·20	178,338	1,835·31	244,903
Nickel Concentrates	2,252·92	381,628	45,272·82	10,128,936
Ochre	261·00	5,220	515·05	9,823
Petroleum (barrels)	4,646,938·00	14,853,605	10,641,703·00	34,015,442
Pyrite	78,684·89	1,067,686	32,879·40	420,825
Rutile	400·00	28,758	845·43	66,754
Semi-precious Stones	28·06	8,042	14·81	10,571
Silver (fine ounces)	309,476·12	420,666	227,653·16	463,733
Talc	7,901·24	227,037	24,724·07	467,706
Tantalo-Columbite	22·75	131,680	493·32	365,504
Tin Concentrate	1,238·71	2,358,771	1,562·78	2,309,788
Tungsten Ore and Concentrate	2·23	4,547	0·61	603
Xenotime	....	....	2·00	4,946
Zircon	29,618·18	1,147,908	28,372·07	899,378
Totals	....	148,555,654	....	205,321,072

* Not available for publication.

Note : The value of mineral and metal production for 1968 was estimated to be between $61 million and $72 million more than the total quoted above.

TABLE 2

Development Footages Reported by the Principal Mines

Gold or Mineral Field	Mine	Shaft Sinking	Driving	Cross Cutting	Rising and Winzing	Exploratory Drilling	Total
Gold—		feet	feet	feet	feet	feet	feet
Murchison	Hill 50 Gold Mine N.L.	173	1,362	402	597	7,523	10,057
East Coolgardie	Lake View & Star Ltd	....	17,159	3,748	2,809	24,266	47,982
	Great Boulder Gold Mines Ltd	....	987	5	294	442	1,728
	North Kalgurlie (1912) Ltd	....	11,535	2,401	813	26,230	40,979
	Gold Mines of Kalgoorlie (Aust.) Ltd	....	14,525	....	5,797	8,893	29,215
Dundas	Central Norseman Gold Corporation N.L.	....	630	....	1,598	51,152	53,380
	Totals in Gold Mines	173	46,198	6,556	11,908	118,506	183,341
Copper— Phillips River	Ravensthorpe Copper Mines N.L.	218	2,097	534	123	1,691	4,663
Lead— Northampton	Canadian Southern Cross Mines N.L.	240	446	214	25	....	925
Nickel— Coolgardie	Western Mining Corporation Ltd	1,090	3,910	1,527	1,605	168,449	176,581
	Totals in All Mines	1,721	52,651	8,831	13,661	288,646	365,510

ASBESTOS

Old dumps at Lionel were the source of the sixty seven tons of chrysotile produced in the Pilbara. At present there are no groups actively engaged in developing or exploiting the chrysotile or crocidolite deposits in Western Australia.

BARITE

Production by *Universal Milling Co. Pty Ltd.* amounted to 656 tons valued at $9,968 f.o.r. Meekatharra. The lode at Chesterfield was worked at depths varying between 95 and 130 feet below the surface.

BAUXITE

Western Aluminium N.L. railed to the Kwinana Refinery 1,607,988 tons of bauxite obtained from Jarrahdale. For the first half of the year mining was concentrated in the rifle range area till the new crushing and train loading plant was completed at Craigs Ridge about three miles north. At the new site, known as Seldom Seen area, mining commenced in July and by the end of the year all production was centred on this area. It is anticipated that production from this area will be increased to 42,000 tons per week.

The crushing plant at the mine site includes an Allis Chalmers gyratory crusher of 1,000 ton per hour capacity crushing to minus 5½ inch. After screening the ore is conveyed to the secondary crusher, an Allis Chalmers Hydrocone which reduces the ore to one inch. The crushed ore is stockpiled over the load out tunnel. Each ore train consists of a diesel engine hauling twenty-two 60-ton capacity wagons.

A further stage in the expansion of the Kwinana Alumina Refinery has been reached by the completion of the third unit of the plant which now has a capacity of about 610,000 tons per annum. Construction of a fourth unit, to raise capacity to 817,000 tons is proceeding. The principal companies participating in Western Aluminium N.L. (wholly owned subsidiary of Alcoa of Australia Pty. Ltd.) are Aluminium Company of America (51%), Western Mining Corporation Ltd. (20%), Broken Hill South Ltd. (16.6%) and North Broken Hill Ltd. (12%).

BENTONITE

Thirty eight tons were obtained during the summer months, from a lake deposit near Marchagee.

BERYL

Thirteen tons containing 152.93 units of beryllium oxide, valued at $5,668, were obtained from the *Australian Glass Manufacturers Co. Pty. Ltd.*'s felspar quarry at Londonderry and from sundry producers at Yinnietharra.

BUILDING STONE

Production from mining tenements granted under the provisions of the Mining Act was 2,211 tons valued at $17,653. Production included 431 tons of quartz from Coolgardie, 1,318 tons of quartzite from Toodyay, 260 tons of tripolite from Kamballup, 185 tons of spongolite from Fitzgerald river and Ravensthorpe, and 17 tons of sandstone from Mount Barker.

CLAYS

Reported clay production from the Metropolitan Area, Byford, Glen Forrest, Red Hill, Goomalling and Clackline totalled 173,744 tons valued at $239,962.

Most of the clay used in the manufacture of cement is obtained from Maida Vale and Armadale. Fireclay is obtained from areas varying from Byford through to Glen Forrest and up to Clackline. Most of this material is taken from private property and supplied to brick makers by contractors. Some white-ball clay from Goomalling is used for pottery purposes.

COAL

The total output from all mines in the Collie Coalfield was 1,087,379 tons valued at $4,816,725. This production was the highest ever recorded on the field and was 25,228 tons higher than the 1967 record output.

The Muja open cut operated by the *Griffin Coal Mining Co. Ltd.* produced 605,160 tons of coal which represented 55.7 per cent. of the total output for the coalfield.

Approximately eighty per cent. of the coal mined in the Cut during the year was won from the Hebe Seam and the remainder was mined from the Hebe Split Seam in the East Extension Area and from the Galatea Seam in Block No. 1. Excluding re-cast overburden which amounted to 55,997 tons, the total quantity of overburden removed was 2,601,167 cubic yards. On the basis of 1 cubic yard of coal "in situ" weighing 1 ton then the ratio of overburden removed to coal produced was 4.3 to 1. Most of the overburden is removed without blasting.

Road formation and maintenance received considerabl attention throughout the year. Significant in new road construction was the provision of a road to connect the floor of the Hebe Seam to the central coal haulage road to Muja generating station. This road has provided for the flow of coal and overburden vehicles to be kept on separate routes, thus minimising traffic congestion and enhancing the safety of the transport system.

Good standards of lighting were maintained in and around excavations, dumps, screening plant and railway siding. The mercury vapour lamps suspended over the excavations from steel ropes spanning from the high wall to the blind outcrop/dump sides are particularly effective in providing good illumination without glare. Overburden dumps and excavation berms were stable throughout the year. Among equipment installed during the year were a Galion grader, a Caterpillar D8 bulldozer and another 50 ton capacity International Payhauler truck.

Western Collieries Ltd. produced 482,219 tons of coal from its two deep mines. Western No. 2 attained a record output of 436,109 tons which was 44,823 tons in excess of the previous year's production. The Western No. 4 mine ceased underground production on the 18th October. During the ten years of underground mining 723,916 tons of coal were won from the Wallsend and Moira seams which averaged 11 feet and 8 feet in thickness respectively. Highest productivity was achieved during the last two years when mining was concentrated on pillar splitting and stripping which was carried out safely and efficiently on a general retreating basis. Eighty per cent. extraction was attained in some areas.

At Western No. 2 mine, development heading drivages continued in the Nos. 4 West, 5 West, 6 West and 6 East Districts and in the Cullen Headings. Development drivages in the No. 1 West group of six headings to the west of the Cullen Headings commenced early in the year. A very soft water bearing floor and "vug" or erosion cavities in the seam and associated strata provided difficulties in the pilot headings of the No. 1 West group. The working areas of the mine are widespread and depths of cover range from approximately 180 feet over the No. 1 West development headings to 480 feet over the No. 6 East "A" panel area. The Wyvern seam which is worked at this colliery averages 11 feet in thickness in the areas being worked. About 2½ feet of coal is left in the roof to form a good parting. Widths of working places vary from 6 to 7 yards while pillar dimensions are arranged to give first working extraction of about 45 per cent. in plan.

Three Harland seven stage 150 h.p. borehole submersible pumps were installed during the year by the State Electricity Commission over the sumpage area to the west of the bottom of the main dips. Each of these pumps handles 30,000 gallons of water per hour which is used in the cooling system at the Muja Generating Station. The total inflow of water into the mine at present is in excess of three million gallons per day.

A health survey of the Collie Miners was carried out in December by the Public Health Department.

COBALT

Ninety one tons of cobalt were contained in nickel concentrates exported by *Western Mining Corporation Ltd.* from its mine at Kambalda.

COPPER

Ravensthorpe Copper Mines N.L. produced 4,276 tons of concentrate from 61,383 tons of ore obtained from the Elverdton and Marion Martin mines. The concentrate contained 963 tons of copper, 1,383 fine ounces of gold and 4,585 fine ounces of silver.

Shaft sinking to the No. 7 level has been completed at the Elverdton, the Marion Martin shaft has been sunk to 305 feet and work is in hand to dewater the Cattlin mine. Ore reserves are quoted as 154,644 tons containing 1.2 per cent. copper. Development work completed during the year includes shaft sinking 218 feet, driving 2,097 feet, crosscutting 534 feet, rising 44 feet and winzing 79 feet.

Western Mining Corporation Ltd. reported the production of 730 tons of metal contained in nickel concentrates exported overseas from its Kambalda operations.

Notable producers of ore for use as a trace element in fertilizers were *R. W. Shearer* at Warriedar with 252 tons of 10 per cent. ore valued at $17,605, *M. Alac* at Ilgarari with 117 tons of 21.2 per cent. ore valued at $15,859, *T. L. Parkinson* at Kumarina with 72 tons of 11.2 per cent. ore valued at $5,913 and *K. J. McPherson* at Glen Ellen pool with 46 tons of 14.6 per cent. ore valued at $5,304. Total production from all sources of this type of ore was 690 tons assaying 13.08 per cent. Cu and valued at $51,231 f.o.r.

DIATOMACEOUS EARTH

Universal Milling Co. Pty. Ltd. reported the production of 43½ tons of calcined diatomaceous earth from deposits in the Yanchep Area.

FELSPAR

Australian Glass Manufacturers Co. reported the production of 469 tons from its quarry at Londonderry in the Coolgardie Goldfield. The company also obtained 738 tons of petalite, 10.45 tons of beryl, and 36 tons of quartz from the same source.

GLASS SAND

Production from the Lake Gnangara deposit amounted to 13,346 tons valued at $18,547. *Ready Mix Concrete (W.A.) Pty. Ltd* and *Silicon Quarries Pty. Ltd.* exported a total of 7,214 tons of silica sand (value not available for publication) obtained from Jandakot.

GOLD

The ore treated during the year amounted to 2,307,737 tons as compared with 2,531,625 tons in the previous year. Gold recovered amounted to 515,950 fine ounces as compared with 573,755 fine ounces for 1967. Grade of ore mined was lower, recovery being 4.47 dwts. per ton as against 4.53 dwts. per ton for 1967.

The calculated value of the gold produced was $16,903,058 which included $779,619 distributed by the Gold Producers Association from the sale of 554,519 fine ounces of gold at an average premium of 143.39 cents per fine ounce. The Mint value of gold throughout the year was $31.25 per fine ounce.

Statistics relating to the gold mining industry are tabulated in Table "3".

Gold Mines of Kalgoorlie (Aust.) Ltd. with a production of 874,883 tons of ore for a return of 153,395 fine ounces of gold at an average recovery of 3.51 dwts. per ton, was the State's leading producer. Production from the Fimiston leases was 297,648 tons yielding 72,455 ounces and from Mount Charlotte 577,235 tons yielding 80,940 ounces.

Ore reserves at Fimiston are stated as 785,000 tons of 4.8 dwts. per ton refractory ore and 79,000 tons of 3.4 dwts. per ton free milling ore. Mount Charlotte reserves are stated as 5,126,000 tons of 3.5 dwts. per ton to the No. 13 level horizon.

Following a large scale development programme the Mount Charlotte mine now has in operation stoping from the 900 feet to 500 feet level. Method of stoping is by sub levels and ring boring. The recovery of pillars in the cut and fill stope, completed above the 500 feet level, is well under way.

At Fimiston, operations were concentrated in workings off the Perseverance shaft. Total development completed by Gold Mines of Kalgoorlie during the year was 29,215 feet made up of 14,525 feet driving, 3,289 feet rising, 2,508 feet winzing and 8,893 feet of exploratory drilling.

Lake View and Star Ltd. produced 130,437 fine ounces of gold from the treatment of 563,114 tons of ore at an average recovery of 4.63 dwts. per ton. The previous year's production was 147,133 fine ounces from the treatment of 638,813 tons.

Estimated ore reserves as at the 1st July were 3,176,900 short tons at 4.70 dwts. per ton.

Development work completed during the year included 17,159 feet driving, 3,748 feet crosscutting, 1,460 feet winzing, 1,349 feet rising and 24,266 feet of exploratory drilling.

The continued shortage of labour caused the decrease in the ore treated for the year, which represented only 74 per cent. of the design capacity of the ore treatment plant. To attract suitable labour the company now has 60 houses available for rental by employees and is investigating the practicability of erecting a further 20 new houses.

Ore production from fill stopes was 34 per cent.

TABLE 3

Principal Gold Producers

Mine	1967			1968		
	Tons Treated	Fine Ounces	Dwts. per ton	Tons Treated	Fine Ounces	Dwts. per ton
Gold Mines of Kalgoorlie (Aust.) Ltd.	864,931	152,569	3·53	874,883	153,395	3·51
Lake View & Star Ltd.	638,813	147,133	4·61	563,114	130,437	4·63
Central Norseman Gold Corporation N.L.	185,224	86,478	9·34	177,275	84,016	9·48
North Kalgurli (1912) Ltd.	356,434	65,302	3·66	348,692	63,578	3·65
Great Boulder Gold Mines Ltd.	295,894	64,410	4·35	191,806	39,733	4·14
Hill 50 Gold Mine N.L.	158,895	40,441	5·09	127,025	32,456	5·11
State Batteries	25,137	8,373	6·66	22,074	7,979	7·23
State Batteries Tailings Treatment	....	3,624	....	....	2,490	....
Other Sources	6,297	5,425	17·23	2,868	1,866	13·01
Totals in all Mines	2,531,625	573,755	4·53	2,307,737	515,950	4·47

of the total. Seismic disturbances caused interruption to stoping operations in the 2 Lode East Branch and Hannans Star West lode areas when level timbers were disturbed.

Central Norseman Gold Corporation N.L. treated 177,275 tons for a recovery of 84,016 fine ounces of gold. Gold recovery was at the rate of 9.48 dwts. per ton as compared with the previous year's recovery of 9.34 dwts. per ton when 185,224 tons yielded 86,478 fine ounces.

Reserves of ore at the end of June were estimated to be 425,000 tons averaging 9.3 dwts. per ton.

Development work was directed to exploring relatively untested areas of Crown deeps and providing access to known ore positions. A total of 630 feet of driving and 1,598 feet of rising were completed as well as 51,152 feet of exploratory diamond drilling.

North Kalgurli (1912) Ltd. treated 348,692 tons of ore for a recovery of 63,578 fine ounces of gold at an average recovery of 3.65 dwts. per ton. During the previous year 65,302 fine ounces were recovered from 356,434 tons of ore.

Preparations have been made to concentrate mining in the deeper workings off the Main Shaft. Development completed during the year included driving 11,535 feet, crosscutting 2,401 feet, rising 585 feet, winzing 228 feet and exploratory drilling 26,230 feet.

North Kalgurli and Great Boulder are associated in a number of joint nickel exploratory ventures which include areas at Scotia, Lake Lefroy, Carr Boyd Rocks, Cowarna Rocks and Ringlock.

Great Boulder Gold Mines Ltd. treated 191,806 tons of ore for a recovery of 39,733 fine ounces of gold at an average recovery of 4.14 dwts. per ton. Production for the previous year was 295,894 tons yielding 64,410 fine ounces at 4.35 dwts. per ton.

Ore reserves at the 30th June were estimated to be 898,100 short tons averaging 4.31 dwts. per ton. Discussions which commenced last year with Lake View and Star Ltd., concerning the feasibility of merging gold mining interests, were broken off in February without reaching agreement. Development work completed during the year included driving 987 feet and rising 294 feet.

The collapse of a pillar between the internal shaft and the ore pass system, below the 3400 level on the 23rd October resulted in the cessation of all mining below that level. All equipment on the 4000 feet level was recovered via Edwards Shaft.

At Mount Martin nickel prospecting continued with the sinking of the old Mount Martin shaft to below 400 feet and cross-cutting to the ore body at that level.

Hill 50 Gold Mine N.L. at Mount Magnet treated 127,025 tons of ore for a return of 32,456 fine ounces of gold, average recovery being 5.11 dwts. per ton.

The company's ore reserve at the 25th June was 462,500 tons at 5.49 dwts. per ton. During the 33 years that this mine has been operating, 2,811,763 tons of ore have been crushed and treated for a return of 1,260,128 fine ounces of gold at an average recovery rate of 8.96 dwts. per ton. The main shaft, 3 compartments 12½ feet x 4½ feet inside timbers, has been sunk to 2,840 feet. The lowest level directly off this shaft is at the 2,760 feet horizon (No. 12 level). Internal service winzes have extended the mine workings to a depth of 3,490 feet.

Development work completed at the *Morning Star* has been the construction of a 799 feet vertical shaft with level development at the 661 and 761 feet horizons. These levels have been connected to workings off the old underlay shaft.

Smaller producers of note were the *Daisy* at Mount Monger with 905 fine ounces from 483 tons, *Star of Mangaroon* in the Gascoyne with 741 fine ounces from 662 tons, *Kitchener* at Bamboo Creek with 557 fine ounces from 309 tons, *Puzzle* at Diorite with 486 fine ounces from 370 tons and Constance Una at Parkers Range with 413 fine ounces from 111 tons.

GYPSUM

Plaster manufacturers obtained their supplies of gypsum from Yellowdine, Lake Brown, Lake Cowcowing and Norseman. Reported production of Plaster of Paris was 27,694 tons from 39,327 tons of gypsum.

Garrick Agnew Pty. Ltd. exported a total of 51,015 tons to Taiwan, Indonesia and Malaysia. This gypsum was obtained from deposits situated near Useless Loop in the Gascoyne Goldfield.

Total gypsum production for the year was 105,019 tons valued at $305,765. Included in this output was 1,563 tons used in the manufacture of cement.

ILMENITE, LEUCOXENE, MONAZITE, RUTILE, XENOTIME, ZIRCON

Sales of ilmenite totalled 464,387 tons valued at $4,559,736. Minerals associated with ilmenite returned $1,296,087 to the producers.

Western Titanium N.L. at Capel produced 215,484 tons of ilmenite assaying 54.46 per cent. titanium dioxide, 920 tons of leucoxene, 1,052 tons of monazite, 845 tons of rutile, 2 tons of xenotime and 17,216 tons of zircon. Hydraulic mining or hydraulicking continued throughout the year to advance the 600 feet wide face at an average of 48 feet per month. The skid mounted wet concentrating plant was moved 600 feet north towards the working face to minimise pumping. The new Jones wet magnetic separator operated satisfactorily. An ilmenite upgrading plant was brought into operation early in the year and production from it is expected to be about 12,000 tons per year.

Western Mineral Sands Pty. Ltd. at Capel produced 122,727 tons of ilmenite assaying 54 per cent. TiO_2. There has been no alteration to the mining method which continues as a sand excavation operation with front end loaders. The wet concentrating plant is installed in the centre of a working area about 20 chains square and about 10 acres is mined each year to produce the above tonnage of ilmenite.

Ilmenite Minerals Pty. Ltd. and Cable (1956) Ltd. wholly owned subsidiaries of Kathleen Investments (Aust.) Ltd. produced 69,566 tons of ilmenite assaying 54.52 per cent. TiO_2, 89 tons of leucoxene, 80 tons of monazite and 938 tons of zircon. The two mining sites are situated at Wonnerup on Sussex location 7 and at Stratham. Revolving cones and Reichert concentrators used in conjunction with a small suction dredge produce approximately 50 tons of concentrate per day from the Wonnerup deposit. The suction dredge with a capacity of 250 tons of sand per hour is still operating at Stratham. Concentrates from both sites are carted to the dry treatment plant at Bunbury.

Westralian Sands Ltd. (previously Westralian Oil Ltd.) produced 56,610 tons of ilmenite assaying 57.76 per cent. TiO_2, 687 tons of leucoxene, 703 tons of monazite and 10,217 tons of zircon. A new wet concentrating plant was installed at Yoganup and nearer to the mining site. The plant has 5 sets of Reichert concentrators. Additional cross belt magnetic separators have been installed at the dry separation plant at Capel.

IRON ORE

Iron ore production exceeded seventeen million tons which was an increase of 71 per cent. on the previous year's output and over 4 times the 1966 production. This State with an output conservatively valued at approximately 124 million dollars is the leading iron ore producer in the Commonwealth.

Hamersley Iron Pty. Ltd. exported 8,139,353 tons of 65.05 per cent. iron ore valued at $70,104,781 f.o.b. Dampier. The company reported the mining of 14.65 million tons of ore and waste at Mount Tom Price. Of this total, 2.25 million tons was low grade ore and waste. The pellet plant at Dampier commenced production in March and is expected to produce 2 million tons of pellets per year.

Mining equipment was increased by the addition of 2 x 12 cubic yard diesel electric shovels and 19 x 100 tons capacity Dart diesel electric trucks. Rates of advance in blast hole drilling have been increased by the purchase of a Bucyrus Erie 60R rotary drill which can drill the required 55 feet deep 10 inch diameter holes at a speed of 110 feet per hour.

At the end of the year the company was employing a work force of 1,126 persons which included 548 at Mount Tom Price, 513 at Dampier and 65 on the railways.

Some 56 miles south of Tom Price, Hamersley Exploration are drilling and sampling the Paraburdoo iron ore deposits. During the year 49,814 feet of percussion drilling and 8,261 feet of diamond drilling were completed as well as a 360 feet adit on the 2,400 feet elevation. Indicated reserves total 250 million tons of high grade haematite.

Goldsworthy Mining Limited reported the sale overseas of 4,395,114 tons of iron ore assaying 65.02 per cent. Fe and valued at $37,106,370 f.o.b. Port Hedland. The workforce has been increased to 540 persons as compared with the previous years' average of 423.

The railway track has been reballasted up by three inches and the completion of six additional bridges is expected by March, 1969. A dust collection unit capable of handling 20 tons per day is being installed at the Goldsworthy crushing plant. At Finucane Island, the installation of a water spray dust suppression system has made a considerable improvement in working conditions. Also under construction at the port is a new stacker-reclaimer and a tertiary crushing and screening plant.

Exploratory work continued at the Shay Gap deposit with the construction of two 101 feet deep shafts spaced approximately 2,000 feet apart. Level development work was completed to define the ore body which is about 500 feet wide and dips to the east at 40 degrees.

Dampier Mining Co. Ltd. produced a total of 4,009,465 tons of iron ore with an average content of 63.62 per cent. Fe and nominally valued at $8,435,260.

Overseas export of Koolan Island ore totalled 91,412 tons averaging 67.02 per cent. Fe and valued at $697,516. Shipments from Cockatoo Island and Koolan Island to the Eastern States totalled 2,686,859 tons having a nominal value of $5,299,977. The company employs 390 men on these two islands. At Koolan five exploratory adits have been driven through the ore body. Reserves at present indicate 12 million tons of 63 per cent. Fe at Cockatoo and 36 million tons of 65 per cent. Fe at Koolan.

Koolyanobbing production was 1,231,194 tons averaging 60.82 per cent. Fe. Of this 669,763 tons were exported from Kwinana to the Eastern States. The 600,000 tons per annum blast furnace was commissioned in May and is supplying Australian and Asian markets with foundry and basic iron. A sinter plant has been added and this enables fines from Koolyanobbing to be converted to sinter which is charged to the blast furnace along with the lump ore. Other raw materials used in iron making are shipped into Kwinana over a new bulk loading jetty. These include coke from Port Kembla, lump limestone from Japan, limesands from South Australia, manganese ore from Groote Eylandt and low phosphorous iron ore from Yampi Sound.

Western Mining Corporation Ltd. mining the Koolanooka Hills deposit exported 634,092 tons of 60.38 per cent. Fe ore valued at $5,094,193 f.o.b. Geraldton. Mining methods were similar to those reported in the 1966 Annual Report. Of the 2,903,322 tons of ore and waste broken during the year 949,274 tons of ore was crushed and stockpiled ready for export.

The Charcoal Iron and Steel Industry at Wundowie obtained 92,400 tons of iron ore from the Koolyanobbing deposit. Pig iron production was 57,888 tons valued at $2,437,767.

LEAD

Sales of lead concentrate, from Northampton, totalled 418 tons containing 311 tons of lead valued at $39,985 f.o.b. Geraldton. The *Mary Springs* lead mine operated by Canadian Southern Cross Mines N.L., was the leading producer with 256 tons of concentrate valued at $27,247. This Company has sunk a new two compartment shaft to 240 feet and has opened up two levels from it.

Other producing mines in the district were the *Nooka* with 98 tons of concentrate valued at $7,797, the *North Ellen* with 36 tons valued at $2,297 and the *Kathleen Hope* with 28 tons valued at $2,644.

LIMESTONE

Reported production of limestone was 964,099 tons valued at $924,511. Total annual production would exceed the figure quoted as not all production is reported. Limestone used for building purposes, road construction, agricultural purposes, flux and cement manufacture was quarried in the metropolitan area, Wanneroo, Mount Many Peaks, Marmion, Jandakot and Eagle Bay.

In the metropolitan area, limestone suitable for use as building stone is valued at about $2.70 per ton while the rubble which is sold principally as a road base is valued between 20 cents and 30 cents per cubic yard.

LITHIUM ORE

Australian Glass Manufacturers Co. obtained 738 tons of petalite from its felspar quarry at Londonderry in the Coolgardie Goldfield.

MAGNESITE

The only producer Norseman Gold Mines N.L. reported the sale of 166 tons obtained from a deposit near Ravensthorpe. Reserves are reputed to be at least 5 million tons.

MANGANESE

Exports from Port Hedland totalled 117,733 tons of 50.63 per cent. Manganese ore valued at $2,649,856. *Mount Sydney Manganese Pty. Ltd.* was the principal producer in the Pilbara with 65,351 tons of 50.17 per cent. Mn ore valued at $1,480,768 f.o.b. Port Hedland. The ownership of the Woody Woody deposits passed to Longreach Manganese Pty. Ltd. on the 2nd September and this company intends to double present annual production.

Accommodation has been improved by the installation of air conditioning in the living quarters.

Westralian Ores Pty. Ltd. sold 52,382 tons of 51.21 per cent. Manganese obtained from M.C. 487 at Woody Woody. The company reported breaking 84,472 tons of ore during the year.

In the *Peak Hill Goldfield,* Westralian Ores Pty. Ltd. produced 27,723 tons of low grade (36.23% Mn) ore from the deposit at Horseshoe. This ore was railed to Geraldton for export.

NICKEL

Western Mining Corporation Ltd. reported the sale of 45,273 tons of concentrate containing 12 per cent. nickel. The estimated nominal value of the nickel in the concentrate exported was $10,128,936. The company reported the breaking of 182,351 tons of ore from workings off the Silver

Lake Shaft at *Kambalda*. Tonnage treated was 154,080 which contained 4,576 tons of nickel plus 572 tons of copper. Ore reserves as at the 19th November were estimated at 13,237,000 tons averaging 3.4 per cent. nickel.

New finds of sulphide mineralisation were located in the Juan and Gellatly shoots which are just west of the Dunkin shoot (area 7) where two 14 feet diameter circular shafts are being sunk about 160 feet between centres. At the end of the year the haulage shaft had reached 476 feet and the service shaft 218 feet. Plats have been cut at the 285 feet and 405 feet levels of the haulage shaft and a plat constructed at the 165 feet level of the service shaft. The Silver Lake shaft has been extended to 1,026 feet with a new plat at 600 feet and a loading station at 700 feet.

Development work completed during the year included shaft sinking 1,090 feet, driving 3,910 feet, crosscutting 1,527 feet, winzing 1,296 feet, rising 309 feet and exploratory drilling 168,449 feet.

In January the company announced that a nickel refinery, capable of producing 15,000 tons of nickel metal per annum, would be established at Kwinana. Work at the site commenced in July.

At Kambalda, 102 houses for mine employees were completed during the year as well as 65 units for single men. A town hall, swimming pool, and bowling green are almost complete and the new shops have been occupied.

OCHRE

Wilgie Mia in the Weld Range was the source of the 515 tons of red oxide obtained by *Universal Milling Co. Pty. Ltd.*

PETROLEUM

Barrow Island crude oil production was 10,641,703 barrels worth $34,015,442 based on a value of $U.S.3.58 per barrel at Kwinana. The development of the Windalia reservoir on an 80 acre spacing was completed by June and by the end of the year production had reached 31,000 barrels per day. Thirty eight water injection wells and two water injection stations were in operation at the end of the year. The jackup drilling barge 'Jubilee' arrived in Western Australia during August and after fitting out at Fremantle it was moved to Quinns Rock No. 1 where offshore drilling commenced in October.

The State's first offshore well, Legendre No. 1 about 100 miles N.E. of Barrow Island, was spudded on 7th June. This well which reached 11,393 feet was drilled by the Glomar Tasman a self propelled drilling vessel.

The report of the Petroleum Engineer covers more fully the activities of the companies engaged in the search for oil in this State.

PYRITE

Norseman Gold Mines N.L. railed to Perth 15,546 tons of pyritic concentrate containing 7,033 tons of sulphur valued at $235,823 f.o.r. Norseman. Production of pyrite from the Iron King mine ceased in June. Closure of the mine was brought about by the decision of superphosphate manufacturers to discontinue the use of pyrite for acid manufacture. Pyrite production commenced in November, 1942 and since that time the company railed to acid manufacturers 1,040,623 tons of concentrate and ore containing 466,441 tons of sulphur valued at $13,968,070. The company is at present investigating salt, magnesite, nickel and gold prospects in the area and crushing road metal for the Main Roads Department.

Gold Mines of Kalgoorlie (Aust.) Ltd. forwarded to works at Fremantle 17,333 tons of auriferous pyritic concentrate containing 7,400 tons of sulphur valued at $185,002.

SEMI PRECIOUS STONES

Production of *chalcedony* from Norseman and *Grants Patch* was 6 tons valued at $2,600. Just under 8 tons of *amethyst* valued at $7,173 was obtained from the Great Australian Amethyst mine in the Ashburton Goldfield. Recovery of *emeralds* from the Poona deposit in the Murchison amounted to 418 carats valued at $798.

SILVER

Silver as a by-product of gold, copper and lead mining amounted to 227,653 fine ounces valued at $463,733.

TALC

Three Springs Talc Pty. Ltds. output trebled as compared with the previous year. The open cut operation was assisted by the employment of contractors to remove overburden. Eight men were employed on Talc production which was 24,724 tons valued at $467,706.

TANTALO-COLUMBITE

493 tons of concentrate containing 3,356 units of Ta205 valued at $365,504 were produced during 1968. This output included 387 tons of low grade material from Cooglegong. Greenbushes production amounted to 81 tons containing 2,142 units recovered as a by-product during tin mining operations. Producing centres in the Pilbara were Cooglegong, Eleys, Wodgina and Moolyella.

TIN

Production for the year was 1,563 tons of concentrate containing 829 tons of the metal valued at $2,309,788. Tin concentrate output from the Pilbara was 1,234 tons and from Greenbushes 329 tons.

Pilbara Tin Pty. Ltd. at Moolyella was the State's leading tin producer with 501 tons of concentrate valued at $1,030,750.

Greenbushes Tin N.L. reported the production of 269 tons of concentrate valued at $546,973. The dredge owned by this company is at present being operated as a stationary concentrating plant and the dry mined ore is carted to the plant from various mining sites.

Cooglegong Tin Pty. Ltd. produced 543 tons of concentrate valued at $311,173. This output included 387 tons of low grade concentrate valued at $20,520.

Other notable tin producers were *J. A. Johnston & Sons Pty. Ltd.* at Eleys with 147 tons of concentrate and the *Vultan Syndicate* at Greenbushes with 52 tons.

TUNGSTEN

Friendly Creek in the West Pilbara Goldfield was the source of 0.61 tons of wolfram containing 34.40 units of WO3.

MINE INSPECTIONS AND ACCIDENT STATISTICS

J. Boyland—Mining Engineer and Senior Inspector of Mines

Hereunder I submit my report for the year ended 31st December, 1968.

Fatal and serious mining accidents reported to the Department are shown below. The corresponding figures for the year 1967 are shown in brackets.

There were 14 (7) fatal and 366 (373) serious accidents.

In gold mines there were 9 (4) fatal and 199 (217) serious accidents. The number of men employed in such mines was 3,887 (4,362). The accident rate per 1,000 men was thus 2.315 (0.917) for fatal accidents and 51.196 (49.74) for serious accidents.

Other fatal accidents were iron ore 3, bauxite 1, rock quarries 1.

Below is a diagram showing fatal accidents segregated according to the class of mining work and extending over the past 20 years.

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

TABLE A

Serious Accidents for 1968

Class of Accident	West Kimberley	Pilbara	West Pilbara	Peak Hill	Murchison	Northampton	Broad Arrow	East Coolgardie	Coolgardie	Yilgarn	Dundas	Phillips River	Greenbushes	South-West	Collie	Ashburton	Gascoyne	Total
Major Injuries—Exclusive of Fatal—																		
Fractures—																		
Head	....	....	....	....	....	....	....	1	....	....	....	1	....	1	....	....	....	3
Shoulder	....	....	1	....	....	....	....	1	....	....	....	....	....	....	....	....	....	2
Arm	1	....	....	....	....	....	....	1	....	....	....	....	....	2	....	....	....	4
Hand	....	....	1	....	....	....	....	2	....	....	....	....	....	....	....	....	....	3
Spine	....	....	....	....	....	....	....	1	....	....	....	....	....	1	....	....	....	2
Rib	....	....	....	....	....	....	....	1	....	....	....	....	....	....	....	....	....	1
Pelvis	....	....	....	....	....	....	....	1	....	....	....	....	....	....	....	....	....	1
Thigh	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Leg	....	1	....	....	....	....	....	3	....	1	1	....	....	4	....	....	....	10
Ankle	....	....	1	....	....	....	....	5	....	....	1	1	....	2	....	....	....	10
Foot	....	1	....	....	....	....	....	....	....	....	....	1	....	....	1	....	....	3
Amputations—																		
Arm	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Hand	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Finger	....	....	....	....	....	....	....	3	1	....	....	....	....	2	....	....	....	6
Leg	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Foot	....	....	....	....	....	....	....	....	....	....	....	....	....	1	....	....	....	1
Toe	....	....	....	....	....	....	....	1	....	....	....	....	....	....	....	1	....	2
Loss of Eye	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Serious Internal	....	....	....	....	....	....	....	....	....	....	....	....	....	3	....	....	1	4
Hernia	....	....	....	....	....	....	....	5	....	....	1	....	....	....	2	....	....	8
Dislocations	....	....	....	....	....	....	....	1	....	....	....	....	....	....	....	....	....	1
Other Major	1	1	2	....	....	....	....	2	....	....	1	....	....	....	....	....	....	7
Total Major	2	3	5	....	....	....	....	28	1	1	4	3	....	16	3	1	1	68
Minor Injuries—																		
Fractures—																		
Finger	1	....	....	....	....	1	....	6	....	....	....	....	....	3	2	....	....	13
Toe	....	....	1	....	....	....	....	2	....	....	....	....	....	1	2	....	....	6
Head	....	2	....	....	2	....	....	7	2	....	....	....	....	2	....	....	....	15
Eyes	....	....	....	1	....	....	....	5	....	....	2	....	....	2	....	....	....	10
Shoulder	....	....	....	....	....	....	....	3	....	....	1	....	....	1	1	1	....	7
Arm	....	1	....	....	....	....	....	4	....	....	2	....	....	1	1	....	....	9
Hand	....	1	2	....	2	....	....	34	3	....	3	1	....	6	7	6	....	65
Back	....	2	2	....	1	....	....	36	2	....	3	3	1	7	12	4	....	73
Rib	....	....	....	....	....	....	....	3	....	....	1	....	....	1	2	1	....	8
Leg	....	1	1	....	....	....	....	21	2	....	2	....	....	2	1	1	....	31
Foot	....	1	....	....	2	....	2	14	1	....	5	....	....	5	3	2	....	35
Other Minor	....	4	1	....	2	....	....	4	....	....	3	....	....	2	3	6	1	26
Total Minor	1	12	7	1	9	1	2	139	10	....	22	4	1	33	34	21	1	298
Grand Total	3	15	12	1	9	1	2	167	11	1	26	7	1	49	37	22	2	366

There were no serious accidents reported in the year under review in the following Goldfields :—Kimberley, East Murchison, Yalgoo, Mount Margaret, North Coolgardie, North-East Coolgardie, Nabberu, Warburton, Eucla.

DIAGRAM OF FATAL ACCIDENTS

SEGREGATED ACCORDING TO CLASS OF MINING

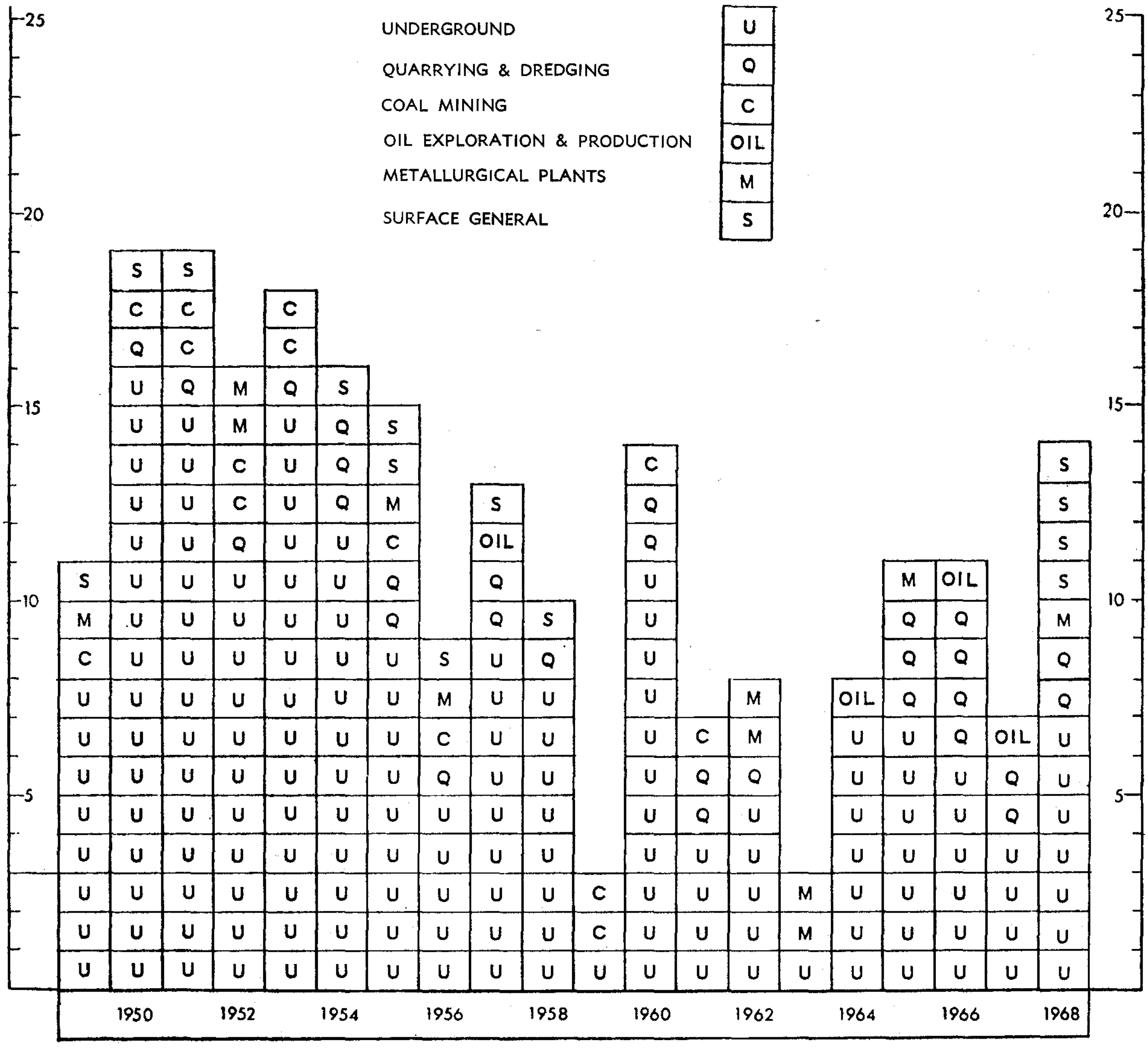

Table 'B' shows the fatal, serious and minor accidents reported and the number of men employed, classified according to the mineral mined.

TABLE B

Accidents segregated according to mineral mined

Mineral	Men Employed	Accidents		
		Fatal	Serious	Minor
Bauxite (Alumina)	724	1	19	27
Coal	649	....	37	187
Copper	128	....	7	31
Gold	3,887	9	199	770
Gypsum	12	....	....	....
Ilmenite	340	....	14	67
Iron Ore	1,295	3	32	248
Lead	22	....	1	....
Manganese	23	....	1	1
Nickel	403	....	13	81
Oil (Production and Exploration)	682	....	36	61
Pyrite	40	....	3	12
Tin	207	....	1	9
Other Minerals	101	....	....	....
Rock Quarries	267	1	3	5
Total	8,780	14	366	1,499

Table 'C' shows the fatal and serious accidents classified according to the accident causes and also shows the different Mining Districts in which the accidents occurred.

TABLE C

Fatal and Serious Accidents showing Causes and Districts

District	Explosives		Falls		Shafts		Fumes		Miscellaneous Underground		Surface		Total	
	Fatal	Serious	Fatal	Serious	Fatal	Serious	Fatal	Serious	Fatal	Serious	Fatal	Serious	Fatal	Serious
Kimberley	....	....	....	....	....	....	....	....	....	....	....	....	....	....
West Kimberley	....	....	....	....	....	....	....	....	....	....	....	3	....	3
Pilbara	....	....	....	....	....	....	....	....	....	....	1	15	1	15
West Pilbara	....	....	....	....	....	....	....	....	....	....	1	12	1	12
Ashburton	....	....	....	....	....	....	....	....	....	....	....	22	....	22
Peak Hill	....	....	....	....	....	....	....	....	....	....	1	1	1	1
Gascoyne	....	....	....	....	....	....	....	....	....	....	....	2	....	2
Murchison	....	....	....	....	1	....	....	....	1	8	....	1	2	9
East Murchison....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Yalgoo	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Northampton	....	....	....	1	....	....	....	....	....	....	....	....	....	1
Mount Margaret	....	....	....	....	....	....	....	....	....	....	....	....	....	....
North Coolgardie	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Broad Arrow	....	....	....	....	....	....	....	....	....	....	....	2	....	2
North-East Coolgardie....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
East Coolgardie	....	1	2	11	1	4	....	....	2	115	2	36	7	167
Coolgardie	....	....	....	1	....	3	....	....	....	1	....	6	....	11
Yilgarn	....	....	....	....	....	....	....	....	....	....	....	1	....	1
Dundas	....	....	....	2	....	1	....	....	....	17	....	6	....	26
Phillips River	....	....	....	2	....	1	....	....	....	4	....	....	....	7
Greenbushes	....	....	....	....	....	....	....	....	....	....	....	1	....	1
South-West	....	....	....	....	....	....	....	....	....	3	2	46	2	49
Collie	....	....	....	1	....	....	....	....	....	30	....	6	....	37
Nabberu	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Warburton	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Eucla	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Total for 1968	....	1	2	18	2	9	....	....	3	178	7	160	14	366
Total for 1967	....	3	2	31	1	6	....	1	....	196	14	136	7	373

FATAL ACCIDENTS

Hereunder is a brief description of fatal accidents reported during the year.

Name and Occupation	Date	Mine	Details and Remarks
Evans, Roy (Machine Miner)	5/3/68	Perseverance Shaft of Gold Mines of Kalgoorlie (Aust.) Ltd	Evans was attempting to free a block ore pass by using a pinch bar. He was above the ore pass and when the blockage was removed, he was pulled into the pass with the ore.
Cox, Keith (Machine Miner)	5/4/68	Edward's Shaft of Great Boulder Gold Mines Ltd	Cox was killed by a fall of rock which " scaled " off the stope. There is a tendency for the backs to " scale " in the mine " deeps " and the ground in question had been examined shortly before the accident.
Howarth, Leslie Francis (Plant Hand)	17/4/68	Western Aluminium N.L., No. 1 Mining Site, Jarrahdale	Howarth entered an ore bin whilst a train was still loading from that bin, and he was drawn through the chute gates and crushed.
Dorazio, Donato (Excavator Driver)	21/5/68	G. H. Reid (W.A.) Pty Ltd, Canna Quarry	Dorazio, an experienced excavator driver, was assisting assemble an excavator after repairs when he was struck by the dipper handle.
Weeber, Fritz Adolf (Machine Miner)	2/6/68	North Kalgurli (1912) Ltd, Main Shaft	Weeber was fatally injured by a fall of rock which apparently slipped from the stope back whilst he was " barring down."
Schmidt, Raymond Hill (Special Mill Hand)	13/6/68	Great Boulder Gold Mines Ltd, Treatment Plant	Schmidt was reported missing at the end of afternoon shift on 13th June, 1968. A search party subsequently found his body immersed in solution in the barren solution tank. It was not ascertained what caused him to be in the tank.
Warburton, Richard Guy (Grader Operator)	5/7/68	Goldsworthy Mining Ltd, Mount Goldsworthy	Warburton was fatally injured when the grader he was driving overturned at a bend on the 300 ft level of the Iron Ore Quarry.
McGillivray, George Hossack (Machine Miner)	9/7/68	Perseverance Shaft at Gold Mines of Kalgoorlie (Aust.) Ltd	McGillivray, an experienced miner, was standing on a ladder attempting to attach an air hose to the air pipe when he fell approximately 20 ft into the stope below and was fatally injured.
Mand, Terrance (Electrician)	10/7/68	Gold Mines of Kalgoorlie (Aust.) Ltd, Surface Power Line	Mand, an experienced electrician, was in charge of a party installing a signal wire on the same poles as 33,000 volt power lines but approximately 4 ft to 5 ft below them. Whilst he was pulling the signal wire, it flicked up and contacted a sagging power line and Mand was electrocuted.

FATAL ACCIDENTS.

Name and Occupation	Date	Mine	Details and Remarks
Watts, Francis Alexander (Machine Miner)	10/7/68	Hill 50 Gold Mine	Watts was a member of a party sinking a winze. Whilst bogging out broken rock the smell of fumes was noted. The two men on shift decided to go up to the level and when the kibble was near the level, Watts fell out of it. He fell approximately 480 ft and was killed instantly.
Marshall, John Walter (Shaft Timberman)	27/7/68	North Kalgurli (1912) Ltd, Kalgurli Shaft	Marshall and his mate, both experienced shaft timbermen, were repairing the shaft timbers from the top of a cage, when suddenly the cage dropped down the shaft out of control and Marshall was fatally injured.
Coutts, Noel (Tractor Driver)	28/11/68	Mount Newman Mining Co., Railroad Construction	Coutts was working driving a tractor on the railway embankment. At approximately 10.40 p.m., when executing a three-point turn, the rear wheels of the tractor apparently went over the edge of the embankment, overturning the tractor, which pinned Coutts underneath.
Martinez, Jair (Machine Miner)	29/11/68	Hill 50 Gold Mine	Martinez was fatally injured when he fell off his working bench, approximately 160 ft, into the stope below.
Figuiera, Jorge Joachim (Labourer)	9/12/68	Mount Newman Mining Co., Mount Newman	Figuiera was fatally injured when he fell from a stationary semi-trialer truck on which he was working and a number of heavy wooden rail sleepers fell on top of him.

WINDING MACHINERY ACCIDENTS

Twelve accidents involving winding machinery were reported during the year.

Derailments—4

On the 28th February during ore hoisting operations in the Regent Shaft of Central Norseman Gold Corporation, the descending North side skip was derailed by spillage just below No. 16 level bin. Slight damage to both shaft timbers and skip resulted.

Whilst running the North side skip through the North Royal Shaft of Central Norseman Gold Corporation prior to lowering the 'day shift' on the 28th November, the skip became derailed below 1000 feet level. There was no damage done to the skip or rope but some shaft timber required replacing.

The skip and 'long tom' were derailed in the skyshaft of the Regent Shaft of Central Norseman Gold Corporation on 6th December. The skip had been blown clear with compressed air and was then taken to the 'tip' it being momentarily forgotten that the 'long tom' was attached. The connecting ropes were damaged.

Spillage at the No. 29 level loading station in the Regent Shaft of Central Norseman Gold Corporation caused the North side skip to be derailed on 26th December.

The skip received a bent axle.

Cage Out of Control—1

On the 27th July two shaft timbermen were repairing timbers in the Kalgurli Shaft of North Kalgurli (1912) Ltd. working from the top of the cage in the North side compartment. This cage with the men on top ran down the shaft out of control when the winder drum brake failed to hold and one man was killed and the other seriously injured. It was established that the brake lining had broken from the brake post.

Obstruction in Shaft—1

On the 26th August after the shaft vehicles had been run through Chaffers Shaft of Lake View and Star Ltd., prior to lowering the shift, it was noticed that the cage was damaged and the rope kinked. Shaft inspection revealed two skids and one shaft centre damaged below No. 12 level loading station. A broken 'slime' pipe had allowed water to run into the shaft and caused the launder lip at the loading station to protrude into the shaft and foul the cage.

Incorrect Operation—1

The rope on the Winder at Oroya South Shaft of Gold Mines of Kalgoorlie (Aust.) Ltd. jumped the drum flange on the 24th December. Two turns of rope were wound on to the brake path; the pivot brackets on the brake post were bent; and the rope was damaged. At the time of the mishap the rope had just been rewound and the driver was taking up the slack. A new rope was required.

Miscellaneous Occurrences—5

Whilst hoisting ore from 2500 level loading station Chaffers Shaft of Lake View and Star Ltd. on February 1st, an electrical failure occurred in the rotor of the motor of the M.G. set supplying D.C. power to the winder motor. The loaded skip was lowered by the brake to the 2000 feet level where it was safely chaired. The winder was out of operation for two weeks.

The gate of the cage in the South Compartment of the Perseverance Shaft of Gold Mines of Kalgoorlie (Aust.) Ltd. fouled the shaft timber near No. 13 level on 26th March. The cage which was damaged was replaced. Prior to the mishap the platmen had been lowering heavy timber and it is thought the timber had lifted the latch of the cage gate.

When four men were in the cage in Silver Lake Shaft Kambalda on the 10th May, the cage gate fouled the shaft timber at No. 4 level and jammed the cage. No one was injured and the cage suffered only slight damage.

On the 19th August when ore was being hoisted in the Croesus Shaft of North Kalgurli (1912) Ltd., the South skip stuck in the 'tip'. The driver's attention must have wandered because when he reversed the engine he let out 700 feet of slack winder rope before he saw it mounting in the engine room and realised that something was wrong. It was necessary to cut the rope to disentangle it, and a new rope was installed.

The south skip became jammed in the sky shaft of Chaffers Shaft Lake View and Star Ltd. on 3rd August. Investigation revealed the skip dump wheels were both outside the guides of the dumping track. It is believed the skip received a jolt, possibly from sudden application of the brakes.

PROSECUTIONS

The registered Manager of a mine was prosecuted for failing to enforce the provisions of the Mines Regulation Act in that he employed a miner for more than 37½ hours below ground in one week, and for a longer period than 7½ hours in one day. The prosecution was successful.

SUNDAY LABOUR PERMITS

Fifty one permits to employ labour on Sundays were issued.

Thirty two of the permits were issued to Gold Mines of Kalgoorlie (Aust) Ltd. to do—

scaling and rock bolting underground at Mount Charlotte;
lowering very heavy equipment;
stripping a main ore pass;
controlling underground water;
installing an underground crusher;
firing misholes and making working safe;
installing a ventilator in the power house;
repairing stope ore pass;
erect a head frame;
instal an ore pass grizzley;
instal a fan underground;
dismantle head frame;
complete compressor cooling tower;
remove old ore bin;
instal underground fuelling station.

The foregoing permits were issued either to prevent loss of time in the subsequent working of the mine or for purposes of safety.

Twelve permits were issued to Western Mining Corporation, Kambalda Nickel operations to—

instal an underground loading station;
instal an underground electrical sub-station;
instal a pump column in a shaft;
establish mine drainage;
remove a shaft pentice;
instal electric cables underground;
strip the ore pass;
make winder foundations underground;
repair an ore pass grizzley;
construct an underground crib-room;
instal a shaft pentice;
instal a pump;
instal permanent steel ventilation ducting;
construct an underground dam.

These permits were issued to avoid loss of time in the subsequent working of the mine.

Central Norseman Gold Corporation were granted three permits to—

excavate an area for a shaft loading pocket;
remove equipment from the internal shaft;
instal a loading platform in the shaft.

The permits were issued for purposes of safety and to avoid loss of time in the subsequent working of the mine.

Lake View and Star Ltd. were permitted to raise ore on one Sunday, following a breakdown in the winder.

One permit was issued to Great Boulder Gold Mines Ltd. to do shaft sinking in the Mount Martin shaft, where the inflow of water required continuous work.

One permit was issued to Western Titanium Ltd. to operate on thirteen Sundays and one permit was issued to Western Mineral Sands to operate on a similar number of Sundays. These permits were granted to prevent dislocation in production.

AUTHORISED MINE SURVEYORS

The Survey Board did not issue any Certificates during the year.

CERTIFICATES OF EXEMPTION
(Section 46)

Three Certificates were issued during the year.

PERMITS TO FIRE OUTSIDE PRESCRIBED TIMES
(Regulation 51)

One permit was granted in relation to sinking isolated shafts.

PERMITS TO RISE
(Regulation 64)

Forty permits were issued for the construction of 54 rises totalling 6880 feet. Forty two of the rises were made using the rising stage method.

VENTILATION

Inspections of the underground workings of all metalliferous mines throughout the State were made during the year. Dust counts and temperatures were recorded and a general appreciation of conditions throughout each mine with particular reference to primary and secondary airflows was ascertained.

Inspections were also made of all crushing reduction and screening installations, including metalliferous treatment plants, blast furnaces, hard-rock quarries, iron ore operations and dry treatment plants associated with the heavy mineral sands industry.

The testing of toxic fumes and vapours associated with the various mine assay laboratories and reduction plants was continued.

Strict control over the use of trackless diesel engine driven equipment in use underground was maintained by the regular sampling and testing of the gases emitted by engine exhaust. All concentrations of the various gases recorded in both undiluted exhaust gases and diluted mine air have been well below the maximum allowable concentrations.

Two occurrences of Methane gas were reported during the year. A diamond drill encountered gas whilst drilling from the No. 9 level the Main Shaft of North Kalgurli (1912) Ltd., but testing proved that there was no dangerous quantity or circumstance.

A diamond drill also encountered a minor pocket of gas at Hill 50 Gold Mine.

During the year the total number of dust samples taken both on the surface and underground was 1781 averaging 236 p.p.c.c. per sample. This once again was an improvement on the previous year when 1312 samples taken averaged 272 p.p.c.c. per sample.

Results of dust counts made during the year are tabulated below. Corresponding figures for 1967 are shown in brackets.

Dust Samples from	Samples Giving Over 1,000 p.p.c.c.	Total Number of Samples	Average Count
Surface Plants	12 (27)	216 (119)	308 (522)
Assay Offices	3 (2)	59 (14)	250 (494)
Stoping	7 (15)	843 (669)	205 (213)
Levels	29 (27)	348 (272)	285 (294)
Development	8 (3)	315 (238)	211 (219)
Totals	59 (74)	1,781 (1,312)	236 (272)

Once again the year was completed without a fatality caused by fumes.

Eight alleged fuming accidents were investigated; only one such occurrence involved loss of time for the man concerned.

Assistance was given to various mines and companies throughout the State in conducting primary and secondary airflow surveys; in endeavours to overcome dust collection problems; or to assist with any other problem associated with ventilation and dust suppression and control.

The urinary sampling of all men employed in the gold mines assay laboratories, and in lead mining at Northampton continued. This work is carried out in conjunction with the Department of Public Health.

Aluminium Therapy.—Provision for the prophylactic treatment with aluminium powder was again available at the gold mines but neither management nor the workforce are interested in this treatment for the prevention of Silicosis and consequently the dispersal of aluminium powder is spasmodic and negligible.

GROUND VIBRATIONS

Our sprengnether seismograph was used to determine ground vibration created by trains, blasting, pile driving, and vibratory rollers. Seismograms were obtained from Underground blasting in Kalgoorlie, as well as from quarry blasting in the Metropolitan urban areas. Vibrations from diesel locomotives used on railways were measured at Toodyay, and vibrations set up by vibratory rollers used in roadworks were measured in Perth and Kwinana areas. Vibrations set up by pile driving for bridge foundations on the Busselton—Yalingup road were measured.

ADMINISTRATIVE

Mines Regulation Act—the *Government Gazette* (No. 68) of 26th July, 1968 contained a notice altering the districts assigned to the various Workmen's Inspectors of Mines.

Regulation 14 was revoked (*Government Gazette* (No. 89)) of 26th September, 1968.

The Mines Regulation Act Amendment Act, 1968 was assented to on 18th November, 1968.

This amendment—

(1) provided interpretations for 'blasting agent', 'emergency', 'foreman', 'mineral', 'quarry', 'rock', 'section', 'shift boss', 'supervisor', 'underground', 'underground manager', and 'underground superintendant';

Amended the interpretations of:

'explosives', 'machinery', 'mine', and 'mining';

(2) deleted reference to animals in both Sections 12 and 22;

(3) amended Section 23 by altering resident or police magistrate to stipendary magistrate;

(4) amended Section 24 to ensure that the 'inspector' was notified of every appointment of a registered manager;

(5) amended Section 25 to provide for Quarry Managers and Quarry Supervisor's certificate;

(6) repealed Section 27 and re-enacted it to ensure that all managers, on appointment, notified the District Inspector of Mines of such appointment;

(7) amended Section 28 to include all classes of managers;

(8) amended Section 30 (2) to provide that inspectors will be notified directly, when a breach of the Act has occurred;

(9) amended—Section 31 to ensure that accidents are reported to the inspector, enlarging the definition of a 'serious accident', and ensuring that the inspector is made aware of all mishaps and unusual occurrences on mines;

(10) repealed Section 32 (1), (2) and (3) to ensure that the inspector makes all enquiries into accidents;

(11) amended Section 34 in accordance with the previous amendment;

(12) repealed Section 36 and re-enacted it to provide that Winding drivers may only be employed for regular hours;

(13) repealed Section 37 and re-enacted it to provide that in emergencies a Winding Driver may work overtime.

(14) repealed Section 38 and re-enacted it to provide that working hours for surface workers coincide with those of relevant industrial awards, but at the same time to limit the number of days worked in a fortnight;

(15) repealed Section 39 and re-enacted it to align the hours worked underground with those of the relevant industrial award but at the same time to limit the days worked, to six per week;

(16) repealed section 40 (1) and re-enacted it to ensure that all the necessary persons could both speak and read the English language;

(17) repealed section 41 and re-enacted it to provide that apprentices and cadets could go underground in the course of their training.

(18) amended section 42, and repealed and re-enacted section 44 to provide for the control of labour on a Sunday, underground;

(19) amended Section 45 in conformity with the previous amendment;

(20) amended Section 46 (1) to provide for the safety of men being raised or lowered by machinery, in any place in a mine;

(21) amended Section 52 to bring it up to date;

(22) amended Section 61 to delete unnecessary items.

Coal Mines Regulation Act—

Regulation 215 (3) was amended to provide adequate allowance for men disabled by accidents.

PETROLEUM

A. J. Sharp—Petroleum Engineer

BARROW ISLAND DEVELOPMENT

The development of the Barrow Island Field, operated by West Australian Petroleum Pty. Ltd., continued. The major development operations were the drilling and completion of production, water injection and water source wells, together with the installation of pipelines and equipment for the commercial scale water flood of the Windalia reservoir. The pilot water flood scheme, initiated in September, 1967, demonstrated that suitable water injection rates could be attained and that a commercial scale water flood to achieve a higher oil recovery was feasible. In April, 1968, the drilling of water injection wells for the commercial scale water flood of the Windalia reservoir commenced. At the year end thirty-eight water injection wells and two water injection stations were in operation. Four additional water injection stations were being constructed. During the year the field produced a total of 10,782,681 bbls. crude oil and 8,656,804 Mcf gas.

OFFSHORE DRILLING

The State's first offshore well, Legendre No. 1 was spudded on 7th June, 1968. This well was drilled by the Glomar Tasman, a self propelled drilling vessel owned and operated by Global Marine Inc. under contract to B.O.C. of Australia Ltd. Legendre No. 1 was drilled to a total depth of 11,393 feet. Logs indicated hydrocarbon bearing zones between 6,272 feet and 6,280 feet and between 6,211 feet and 6,227 feet. The well was plugged back 6,797 feet and the two intervals tested separately. The interval 6,272 feet to 6,280 feet produced salt water only. The interval 6,211 feet to 6,227 feet flowed crude oil at the rate of approximately 1,000 bbls/day on a ⅝ths inch choke. After testing the well was plugged, a corrosion cap installed and the well left in a condition which will allow it to be re-entered. On the 18th November, 1968, the Glomar Tasman was moved to Dampier No. 1 location and at the year end was drilling at a depth of 8,611 feet.

The Jubilee, a jack-up drilling barge, owned and operated by the Offshore Company of Texas, was used by West Australian Petroleum Pty. Ltd. to drill the offshore wells, Quinns Rock No. 1 and Gage Roads No. 1. Quinns Rock No. 1 spudded on the 10th October, 1968, was drilled to a total depth of 7,248 feet. No hydrocarbons indications were encountered and the well was plugged and abandoned. The Jubilee was then moved to Gage Roads No. 1. This well was spudded on the 27th November, 1968 and at the year end had drilled to a depth of 6,976 feet.

LAND EXPLORATION DRILLING

Twenty-four land exploration wells were drilled in the State during 1968. All the land exploration wells were plugged and abandoned with the exception of Flacourt No. 1 (Barrow Island) which was completed as an oil producer and Mondarra No. 1 which was completed as a potential gas producer. The discovery of gas at the West Australian Petroleum Pty. Ltd. well, Mondarra No. 1, in November, 1968 was followed by the drilling of Mondarra No. 2 approximately 2¾ miles south of Mondarra No. 1. At the year end Mondarra No. 2 had reached a depth of 6,783 feet. Further drilling in early 1969 is planned by West Australian Petroleum Ltd. in the Dongara and Mondarra fields to evaluate the gas reserves in this area.

ROTARY DRILLING RIGS ACTIVE IN 1968

Drilling Rig	*Operated by*
Glomar Tasman	Global Marine Australasia Pty. Ltd.
Jubilee	Offshore Drilling W.A. Pty. Ltd.
Land	
National 100	Richter Bawden Drilling Pty. Ltd.
Ideco DIR 552	Richter Bawden Drilling Pty. Ltd.
National 80B	Oil Drilling and Exploration Ltd.
Ideco Jr. Super 7-11	Oil Drilling and Exploration Ltd.
Ideco Super 7-11	Oil Drilling and Exploration Ltd.
Ideco H35 Rambler	Oil Drilling and Exploration Ltd.
Ideco H525	Oil Drilling and Exploration Ltd.
Ideco H40	Oil Drilling and Exploration Ltd.

(In addition to the rigs listed there are a number of small rotary rigs operating in the State.)

DRILLING OPERATIONS

D. A. Macpherson—Drilling Engineer

During 1968, the Drilling Section was responsible for the drilling of 35,040 feet in 78 bores, the work being done partly by Departmental employees and equipment and partly by private drillers under contract to the Department.

A brief resumé of each job follows and a table of the work carried out is given at the end of this report.

ORD RIVER

This job was done on an urgent basis to provide information vital to the completion of the Ord River Dam design and contract specifications and was financed by the Public Works Department. There were three distinct phases:—

(1) Diamond core drilling the spillway to prove rock quality.

(2) Drilling through alluvium on the main dam axis and core drilling underlying strata to allow estimation of foundation excavation quantities.

(3) Diamond core drilling quartzite in two proposed sites for rock quarries, to prove quality and quantity of available rock.

Phase 2 involved drilling from a barge floating in the Ord River with attendant difficulties due to variations in river flow.

Phase 3 required the use of a helicopter to move the drill, men and supplies to the otherwise inaccessible sites.

The job was done by Department of Mines plant and personnel.

CUE

This job was done to finalise a groundwater investigation in the Cue area and was financed by the Department of Mines.

It consisted of preparing previously drilled bores for testing, drilling some additional observation bores and carrying out pumping tests on the 3 main bores.

Bore yields were extremely high, one 12 in. bore being pumped at the rate of 130,000 gallons per hour for 5 days, with a resultant drop in water level of only 1.8 feet.

The work was carried out by Department of Mines plant and personnel.

AGATON

This job was done to investigate the possibility of obtaining substantial additional water for the Northern Comprehensive Water Scheme from underground sources in the area west of Watheroo, and was financed by the Public Works Department.

The work involved drilling bores by cable tool (to 1000 feet) and rotary (to 2500 feet) methods, and subsequent testing of selected bores.

The size of this job (27,786 feet drilled for the year) together with the urgency attached to it placed considerable strain on the Section's supervisory personnel. Difficulties were encountered throughout the work due to the sandy terrain and unconsolidated strata penetrated by the boreholes.

The bulk of the work was done by contractors under Department of Mines supervision, the remainder being done by Departmental plant and personnel. The main rotary contractor used a Department plant under a hire arrangement.

NORTHAM AND WOOLGANGIE

These jobs were part of the upper Mantle Investigations being conducted by the Australian National University, which financed the work.

The jobs were similar, each requiring diamond coring a borehole to 1000 feet in granite to provide core samples for detailed examination and a facility for measuring certain properties of the earth's upper mantle, particularly thermal gradient.

The work was done by a contractor under Department of Mines supervision.

GNANGARA

This job was part of a groundwater investigation programme in which satisfactory bores were finalised as water supply facilities, undertaken for the Metropolitan Water Supply, Sewerage and Drainage Board and financed by that Department.

The work entailed drilling shallow bores by cable tool methods and prolonged testing of the bores to allow determination of safe yields.

The work was carried out by Department of Mines plant and personnel.

BUNBURY

This job was done to provide information on the strata underlying Bunbury Harbour, required in the design of extensions and deepening of the

TABLE SHOWING WORK CARRIED OUT DURING YEAR ENDED 31/12/68

Place	Purpose	Type of Work	Construction by	No. of Bores	Footage
Ord River	Damsite Investigation	Diamond Drilling	Dept. of Mines	17	2,270
Cue	Groundwater Investigation	Cable Tool Drilling	Dept. of Mines	4	178
		Bore Testing	Dept. of Mines	3	
Agaton	Groundwater Investigation	Cable Tool Drilling	Dept. of Mines	3	1,702
			Contractors	7	7,009
		Rotary Drilling	Dept. of Mines	1	1,020
			Contractors	14	18,055
		Bore Testing	Dept. of Mines	1	
			Contractors	10	
Northam	Upper Mantle	Diamond Drilling	Contractor	3	1,171
Woolgangie	Upper Mantle Investigation	Diamond Drilling	Contractor	1	1,000
Gnangara	Groundwater Investigation	Cable Tool Drilling	Dept. of Mines	3	462
		Bore Testing	Dept. of Mines	3	
Bunbury	Harbour Investigation	Rotary Drilling	Dept. of Mines	9	525
		Diamond Drilling	Dept. of Mines	10	486
Albany	Groundwater Investigation	Cable Tool Drilling	Dept. of Mines	3	634
			Contractor	3	528
		Bore Testing	Dept. of Mines	2	
			Contractor	3	
			Total Footage		35,040

Harbour. The work was carried out on behalf of and financed by, the Harbours and Rivers Branch of the Public Works Department.

The job involved 2 separate phases:—

(1) Drilling on the Harbour foreshores using a rotary drill to take cores of hard strata.

(2) Drilling in the Harbour through sands and diamond core drilling underlying hard strata.

Phase 2 involved drilling from a barge floating in the Harbour with some loss of time due to excessive barge motion in rough weather.

The work was carried out by Department of Mines plant and personnel.

ALBANY

This job was done to investigate the possibility of obtaining water for Albany from groundwater sources additional to those already being utilised. The work was carried out for, and financed by, the Public Works Department.

The work consisted of construction of bores by cable tool methods and subsequent testing of the bores to determine quality and quantity of available water.

Approximately half the work was carried out by a contractor under Department of Mines supervision and the remainder by Departmental plant and personnel.

In September, the Drilling Store and Workshop was moved to new premises in Harris Street, Carlisle, the vacated premises at Welshpool being taken over by Chamberlain Industries for expansion of their works. The new premises have given much better stores, workshop and office facilities, and much better working conditions for employees.

Major items of new plant placed in service during 1968 were as follows:—

1 only 7 ton short wheel base 4 x 4 diesel truck primarily intended for transport of mud handling equipment and water for rotary drilling plants.

1 only diesel engined shaft driven bore hole turbine pump unit for testing bore yields.

Various items of plant which had reached the end of their economic life were replaced.

BOARD OF EXAMINERS

FOR MINE MANAGERS' AND UNDERGROUND SUPERVISORS' CERTIFICATES

W. J. Cahill—Secretary

Herewith I submit the Annual Report on the activities of the Board of Examiners for the year 1968.

A special meeting of the Board was held at the State Mining Engineer's office, Perth on Friday, 27th January, 1968 to discuss the academic qualifications and experience of some thirty four (34) applicants for positions of District Inspectors of Mines and Mining Engineers in the State Mines Department. After reviewing all applications, nine (9) were considered to have the necessary qualifications and experience.

Mining Law Examination

An examination in Mining Law for the Mine Manager's Certificate of Competency was held on 22nd April, 1968.

Details were as follows:—

Entries	7
Admitted	7
Pass	4

The names of the successful candidates were:—

First Class

W. S. Padgett.
L. F. Christopher.
G. Munro.

Second Class

P. R. Daly.

Underground Supervisor's Examination

The written examination was held on 3rd September, 1968 and applications were received from the following centres:—

Kalgoorlie	14
Mt. Magnet	1
Norseman	3
Northampton	2
	20

Of the twenty (20) applications received, eighteen (18) were accepted. One application from Norseman and one from Northampton being rejected.

One applicant from Kalgoorlie Mr. R. C. Parsons, was required to sit for the Mining Law Section only as he had passed the mining at a previous examination in 1967.

The results were as follows:—

Passed	16
Failed	1
Did not sit	1

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

E. Abram—Kalgoorlie
J. J. Bermingham—Kalgoorlie
E. Botica—Kalgoorlie
C. G. Brown—Kalgoorlie
J. Campbell—Kalgoorlie
J. E. W. Davies—Kalgoorlie
E. J. Felton—Kalgoorlie
R. J. McQuiggin—Kalgoorlie
R. Panizza—Kalgoorlie
R. C. Parsons—Kalgoorlie
R. J. Patrizi—Kalgoorlie
C. Roach—Kalgoorlie
R. C. Watts—Kalgoorlie
R. D. Meagher—Norseman
C. Vetrone—Mount Magnet
P. D. Brown—Northampton

Mine Manager's Certificates

The following were successful applicants for Mine Manager's Certificates:

First Class

R. J. Lea.
L. F. Christopher.
G. Munro.

An application for the issue of a Second Class Certificate was refused on the grounds that the applicant (a) had not completed the School of Mines Second Class Mine Manager's Course and (b) had insufficient Mining experience. The application fee was refunded.

General

Five meetings of the Board were held during the year. The Board of Examiners visited the following centres during the year and examined candidates orally for the Underground Supervisor's Certificate of Competency:—

Kalgoorlie, Norseman, Mount Magnet, Northampton.

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DIVISION III

Report of the Superintendent of State Batteries—1968

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, 1968.

Crushing Gold Ores

One 20 head, four 10 head, and ten 5 head mills crushed 22,074¼ tons of ore made up of 291 separate parcels, an average of 75.86 tons per parcel. The bullion produced amounted to 9,415 ozs. which is estimated to contain 7,979 ozs. of fine gold, equal to 7 dwts. 5 grs. of gold per ton of ore.

The average value of the ore after amalgamation, but before cyanidation was 2 dwts. 16 gr. Thus the average head value of the ore was 9 dwts. 21 grs. which is 12 grs. more than the previous year's average.

A total of 11½ tons of tantalite-columbite ore was also crushed at the plants that usually crush mainly gold ores. The average cost for crushing the 22.085¾ tons was $13.68 per ton, compared with 1967 when 25,646¼ tons were crushed at a cost of $12.27 per ton.

Cyaniding

Nine plants treated 16,270½ tons of tailings from amalgamation for a production of 2,490 fine ozs. of gold worth $75,356. The average content was 4 dwts. 1 gr. before cyanidation, while the residue after treatment averaged 1 dwt. The theoretical extraction was, therefore, 75.32%. The actual extraction was 75.58%.

The cost of cyaniding was $7.75 per ton, higher than the previous year, when 19,851 tons were treated at a cost of $6.27 per ton.

Some silver has always been recovered by cyaniding gold tailings, but the amount and value has previously been so small that receipts for silver recovered have been included in the value of the gold production. This year some tailings treated at the Marvel Loch Battery contained unusually high silver values and treatment methods were modified to give maximum silver recovery. At this Battery 1,661.8 fine ozs. silver, valued at $2,532.05 were recovered by cyaniding. At all Batteries 1,828.9 fine ozs. silver valued at $2,786.95 were recovered during the year by cyanide treatment.

TREATMENT OF ORES OTHER THAN GOLD

Lead Ores

During the year the Northampton State Battery crushed 3,072¾ tons of lead ore with an estimated average content of 17.47% lead. There were 17 separate parcels, giving an average of 180.75 tons of ore per parcel.

A total of 658.89 tons of concentrates was produced. The concentrates averaged 70.37% lead giving an estimated content of 463.64 tons of lead in concentrates.

2,413.86 tons of tailings were discarded. These had an average content of 3.03% lead, giving a total of 73.12 tons of lead discarded in tailings.

The recovery of lead in the concentrates was 86.38% of the lead in the ore delivered to the plant.

The cost of operating the Northampton State Battery, including administration, was $38,990.64 being $12.69 per ton of ore crushed. Revenue received was $6,145.50 being $2.00 per ton. The corresponding figures for 1967 when 3,273¾ tons of ore were crushed, were operating cost $30,737.39, $9.39 per ton, and revenue $6,547.75, $2.00 per ton.

Tin Ore

No tin ore was crushed for the year, but a magnetic separator plant to clean alluvial tin concentrates commenced operations at the Marble Bar State Battery. This plant treated 52 tons of low grade concentrates for the recovery of 92,525 lb. of high grade tin concentrates valued at $79,720.

Tantalite-Columbite Ores

The Marble Bar Battery crushed 11½ tons of tantalite ore for the recovery of 35 lb. concentrates.

From the Marble Bar magnetic plant, 1,429 lb. of tantalite concentrates were recovered from the tin concentrates treated.

The 1,464 lb. of tantalite concentrates are valued at $1,657.

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

	1968 $	Grand Total $
Par Production—		
Crushing	67,789	18,086,814
Cyanidation	18,642	4,458,295
Gold Premium—		
Crushing	181,569	12,249,424
Cyanidation	56,714	3,394,901
Open Market Premium—		
Crushing	11,442	82,334
Cyanidation	3,571	26,466
Total Gold Production	$339,727	$38,298,234

OTHER ORES REALISED

	1968 $	Grand Total $
Silver	2,787	2,787
Tin—		
Ores and Concentrates	79,720	298,607
Residues	....	1,144
Tungsten Concentrates	....	38,896
Agricultural Copper Ore	....	11,932
Lead Concentrates	62,594	1,192,278
Tantalite-Columbite Concentrates	1,657	30,981
Total Other Ores	$146,758	$1,576,625
Grand Total	$486,485	$39,874,859

FINANCIAL

	Tons	Expenditure $	Receipts $	Loss $
Crushing (Gold Mills)	22,085¼	302,240	24,632	277,608
Magnetic Separator Plant (Marble Bar)	52	5,711	2,013	3,698
Crushing Lead Mill (Northampton)	3,072¾	38,990	6,145	32,845
Cyaniding	16,270½	130,469	47,935	82,534
	....	$477,410	$80,725	$396,685

The loss of $396,685 is an increase of $3,667 on the previous year. It does not include depreciation and interest on capital.

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

		$
Lake Darlot	Power Plant and Residue Disposal	12,432.15
Marble Bar	Plant to treat Low Grade Alluvial Tin Concentrate	10,483.25
Northampton	Battery Improvements	14,110.32
		$37,025.72

Cartage Subsidies

	Tons	Cost
Ore carted to State Plants	9,918½	$12,225

Comparative Figures for the last three years are:—

Year	State Plants				Private Plants		
	Tons Crushed	Tons Subsidised	Per cent. Subsidised	Cost	Tons Subsidised	Cost	Total Cost
				$			$
1966....	35,855½	10,442¾	29·12	14,202	*Nil*	*Nil*	14,202
1967....	28,920	12,516	43·21	16,795	*Nil*	*Nil*	16,795
1968....	25,210½	9,918½	39·34	12,225	*Nil*	*Nil*	12,225

Administrative

Expenditure amounted to $69,785.59 equivalent to $1.68 per ton of ore crushed and cyanided, compared with an expenditure of $66,247.17, $1.29 per ton, for 1967.

	1967	1968
Salaries	42,298.74	43,346.60
Pay Roll Tax	7,458.98	7,724.04
Workers' Compensation	7,873.31	6,485.35
Travelling and Inspection	6,622.27	8,069.68
Sundries	1,993.87	4,159.92
	$66,247.17	$69,785.59

Staff

After some 15 years loyal service Manager Thompson retired in August. Alf Thompson will be well remembered in many goldfields, but particularly in the Pilbara where he worked on mines for many years before joining the State Batteries.

Manager Stevens was transferred from Leonora to Norseman.

Manager Turner was transferred from Menzies to Leonora.

H. Sparrowhawk was appointed Manager at Menzies.

General

Again there was a reduction in the amount of gold ore crushed, from 25,137 tons in 1967, to 22,074½ tons in 1968. The reduction was in the first six months of the year when less than 8,000 tons were crushed. During the second half of the year over 14,000 tons were crushed and increased activity is indicated for 1969.

The 10 head stamp battery at Cue was almost completely destroyed by fire in February. The fire started in the engine room and burning oil quickly ignited the timber in the mill frame, bins, and building. Fire extinguishers then fire hoses manned by the Cue Volunteer Fire Brigade were used, but the fire could not be controlled until most of the timber had been burnt. The Cue State Battery had crushed very little ore for some years and it was decided that the plant would not be rebuilt until there is a considerable increase in gold mining in the district.

Cyaniding continued satisfactorily, and stocks of untreated tailings were further reduced.

The Northampton Battery crushed only 3,072¾ tons of lead ore for the year, but there will be a big increase in 1969. The Mary Springs Mine started producing over 1,000 tons of ore per month in November 1968 and this rate has continued into 1969. Alterations have been made to the plant to crush the increased supplies of ore.

A magnetic separator plant, to clean and separate tantalite from tin concentrates produced by the smaller alluvial workings started operating at Marble Bar early in the year. After initial troubles the plant worked satisfactorily producing high grade tin concentrates and recovering marketable tantalite concentrates, but the amount treated was considerably less than anticipated.

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, 1968

Number of Parcels Treated	Battery	Tons Crushed	Yield by Amalgamation				Amalgamation Tailings Content		Contents of Ore-Fine Gold			
			Bullion		Fine Gold				Total		Per Ton	
			Ozs.	Dwts.	Ozs.	Dwts.	Ozs.	Dwts.	Ozs.	Dwts.	Dwts.	Grs.
9	Boogardie	438·00	80	10	68	5	24	3	92	8	4	5
45	Coolgardie	2,821·75	720	6	610	9	222	2	832	11	5	22
78	Kalgoorlie....	7,459·25	2,941	1	2,492	11	701	2	3,193	13	8	14
18	Lake Darlot	1,103·50	548	12	464	19	103	10	568	9	10	7
16	Leonora	1,525·50	931	7	789	6	531	9	1,320	15	17	8
22	Marble Bar	1,394·50	1,008	17	855	0	359	10	1,214	10	17	10
28	Marvel Loch	1,741·00	1,075	0	911	1	239	9	1,150	10	13	5
6	Meekatharra	1,664·00	259	14	220	2	191	5	411	7	4	23
19	Menzies	1,575·00	427	3	362	0	300	7	662	7	8	10
5	Norseman	218·00	124	15	105	15	50	7	156	2	14	8
31	Ora Banda	1,033·00	815	19	691	10	109	19	801	9	15	12
10	Paynes Find	530·00	212	4	179	17	33	11	213	8	8	1
1	Sandstone	47·75	137	12	116	12	12	5	128	17	53	23
1	Yarri	367·00	95	0	80	10	18	7	98	17	5	9
2	Nullagine	156·00	37	3	31	10	30	14	62	4	7	23
291		22,074·25	9,415	3	7,979	7	2,928	0	10,907	7	9	21

Average Tons per Parcel .... 75·86
Average Yield by Amalgamation per ton (Fine Gold) .... 7 dwts. 5 grs.
Average Value of Tailings per ton (Fine Gold) .... 2 dwts. 16 grs.

Schedule No. 2

DETAILS OF EXTRACTION TAILINGS TREATMENT 1968

Battery	Tons Treated	Head Value			Tail Value			Calculated Recovery		Actual Recovery	
		Per Ton		Total content	Per Ton		Total content				
		Dwts.	Grs.	Ozs.	Dwts.	Grs.	Ozs.	Ozs.	%	Ozs.	%
Coolgardie	2,550	3	21	495·25	0	23	123·95	371·30	74·97	380·20	76·77
Cue	1,560	3	4	246·45	0	19	60·95	185·50	75·27	178·01	72·23
Kalgoorlie	5,400	3	17	1,003·10	0	21	237·80	765·30	76·29	755·84	75·35
Lake Darlot	3,360	3	6	544·05	0	18	128·45	415·60	76·39	410·56	75·46
Leonora	182	11	10	104·00	8	9	76·30	27·70	26·63	29·29	28·16
Marble Bar	1,056	7	5	381·70	1	8	71·05	310·65	81·39	334·16	87·54
Marvel Loch	1,580	4	16	367·05	1	1	83·00	284·05	77·39	285·99	77·92
Norseman	420	4	3	86·80	0	19	16·20	70·60	81·34	68·70	79·15
Ora Banda	162½	8	5	66·65	1	21	15·35	51·30	76·96	47·70	71·56
	16,270½	4	1	3,295·05	1	00	813·05	2,482·00	75·32	2,490·45	75·58

Schedule No. 3

DIRECT PURCHASE OF TAILINGS FOR THE YEAR ENDED 31st DECEMBER, 1968

Battery	Tons of Tailings Purchased	Initial Payment to $28 per Fine oz.
		$
Boogardie	65·00	89.08
Coolgardie	352·75	767.84
Kalgoorlie	1,234·00	5,154.23
Lake Darlot	400·75	1,200.62
Leonora	1,082·25	3,684.93
Marble Bar	998·50	3,449.83
Marvel Loch	807·25	1,636.67
Menzies	227·00	3,630.18
Norseman	229·00	717.25
Nullagine	140·00	235.16
Ora Banda	102·25	1,081.35
Paynes Find	9·00	62.98
Sandstone	43·00	126.07
	5,690·75	21,836.19

Schedule No. 4

STATEMENT OF RECEIPTS AND EXPENDITURE FOR THE YEAR ENDED 31st DECEMBER, 1968

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	438·00	3,654.81	1,650.64	640.05	5,945.50	13.57	1,805.17	1,430.39	9,181.06	20.96	635.01	1.45	....	8,546.05
Coolgardie	2,821·75	4,745.79	7,818.00	3,312.14	15,875.93	5.63	5,878.88	5,801.22	27,556.03	9.76	2,758.30	.97	....	24,797.73
Cue	....	569.70	....	....	569.70	....	....	....	569.70	....	259.23	....	....	310.47
Kalgoorlie	7,459·25	11,370.73	14,976.82	9,482.30	35,829.85	4.80	11,984.73	15,713.95	63,528.53	8.52	7,423.14	.99	....	56,105.39
Lake Darlot	1,103·50	3,178.36	7,073.98	2,466.75	12,719.09	11.53	8,361.11	4,039.38	25,119.58	22.76	1,541.03	1.40	....	23,578.55
Laverton	....	....	371.29	6.50	377.79	....	94.77	205.35	677.91	....	9.24	....	....	668.67
Leonora	1,525·50	6,589.52	6,219.82	2,709.99	15,519.33	10.17	2,758.07	3,906.21	22,183.61	14.54	2,500.21	1.64	....	19,683.40
Marble Bar	1,406·00	7,587.16	8,990.27	4,576.40	21,153.83	15.05	8,787.00	4,816.92	34,757.75	24.72	1,917.18	1.36	....	32,840.57
Marvel Loch	1,741·00	5,074.02	7,959.53	2,620.76	15,654.31	8.99	1,990.07	4,438.87	22,083.25	12.68	1,834.28	1.05	....	20,248.97
Meekatharra	1,664·00	5,135.69	3,707.36	3,346.44	12,189.49	7.33	3,603.68	4,889.96	20,683.13	12.43	1,019.67	.61	....	19,663.46
Menzies	1,575·00	4,944.09	4,801.54	3,362.72	13,108.35	8.32	4,337.24	3,979.25	21,424.84	13.60	1,657.36	1.05	....	19,767.48
Norseman	218·00	2,774.86	2,321.72	1,378.32	6,474.90	29.70	2,495.10	1,525.59	10,495.59	48.14	329.63	1.51	....	10,165.96
Nullagine	156·00	209.72	1,830.62	289.12	2,329.46	14.93	865.16	1,441.85	4,636.47	29.72	164.35	1.05	....	4,472.12
Ora Banda	1,033·00	4,864.67	4,947.48	2,087.54	11,899.69	11.52	5,348.20	2,406.65	19,654.54	19.03	1,377.77	1.33	....	18,276.77
Paynes Find	530·00	2,885.68	2,493.85	1,393.52	6,773.05	12.78	2,101.70	2,001.47	10,876.22	20.52	671.97	1.27	....	10,204.25
Peak Hill	....	....	....	18.69	18.69	....	36.27	....	54.96	....	....	....	....	54.96
Sandstone	47·75	249.86	492.15	124.61	866.62	18.15	47.80	231.70	1,146.12	24.00	67.37	1.41	....	1,078.75
Yarri	367·00	....	2,089.82	2,208.06	4,297.88	11.71	1,449.73	1,863.63	7,611.24	20.74	421.35	1.15	....	7,189.89
Head Office	....	....	....	....	....	....	....	....	....	....	45.02	....	45.02	....
Sub-Total	22,085·75	63,834.66	77,744.89	40,023.91	181,603.46	8.22	61,944.68	58,692.39	302,240.53	13.68	24,632.11	1.12	45.02	277,653.44
Northampton (Lead)	3,072·75	8,485.28	5,382.60	5,155.39	19,023.27	6.19	13,777.41	6,189.96	38,990.64	12.69	6,145.50	2.00	....	32,845.14
Marble Bar (Magnetic Separator Plant)	52·00	643.15	1,196.73	1,258.30	3,098.18	59.58	1,168.44	1,443.91	5,710.53	109.82	2,013.00	38.71	....	3,697.53
Total	25,210·50	72,963.09	84,324.22	46,437.60	203,724.91	8.08	76,890.53	66,326.26	346,941.70	13.76	32,790.61	1.30	45.02	314,196.11

OPERATING LOSS $314,151.09

Schedule No. 5

STATEMENT OF RECEIPTS AND EXPENDITURE FOR THE YEAR ENDED 31st DECEMBER, 1968

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	2,550·00	1,770.01	8,262.59	4,802.12	14,834.72	5.82	2,812.50	4,022.61	21,669.83	8.50	7,338.75	2.88	....	14,331.08
Cue	1,560·00	5,175.94	8,757.73	6,897.89	20,831.56	13.35	2,995.49	3,186.00	27,013.05	17.32	2,916.85	1.87	....	24,096.20
Kalgoorlie	5,400·00	4,248.18	9,289.19	5,010.62	18,547.99	3.43	825.94	10,526.66	29,900.59	5.54	14,603.85	2.70	....	15,296.74
Lake Darlot	3,360·00	1,435.62	5,025.72	3,457.59	9,918.93	2.95	1,606.99	7,244.06	18,769.98	5.59	8,468.71	2.52	....	10,301.27
Leonora	182·00	....	288.62	242.41	531.03	2.92	36.00	586.58	1,153.61	6.34	1,153.61	6.34	....	....
Marble Bar	1,056·00	808.02	4,085.73	1,130.88	6,024.63	5.71	98.48	1,411.94	7,535.05	7.14	5,562.41	5.27	....	1,972.64
Marvel Loch	1,580·00	193.19	4,201.63	2,140.63	6,535.45	4.14	20.44	2,155.28	8,711.17	5.51	5,778.19	3.66	....	2,932.98
Norseman	420·00	1,912.66	2,551.22	2,516.22	6,980.10	16.62	659.41	1,442.69	9,082.20	21.62	652.12	1.55	....	8,430.08
Ora Banda	162·50	608.84	285.64	513.24	1,407.72	8.66	360.64	544.72	2,313.08	14.23	1,460.19	8.99	....	852.89
Total	16,270·50	16,152.46	42,748.07	26,711.60	85,612.13	5.26	9,415.89	31,120.54	126,148.56	7.75	47,934.68	2.95	....	78,213.88
Interest Paid to Treasury									4,320.00					4,320.00
									130,468.56		47,934.68			82,533.88
Operating Loss														82,533.88

STATE BATTERIES

TRADING AND PROFIT LOSS ACCOUNT FOR THE YEAR ENDED 31st DECEMBER, 1968

1967		1968	
$		$	$
	Trading Costs—		
231,805	Wages	216,188	
78,905	Stores	73,149	
69,917	Repairs, Renewals and Battery Spares	86,306	
93,622	General Expenses and Administration	101,767	
474,249			477,410
	Earnings—		
81,231	Milling and Cyaniding Charges		80,725
393,018	Operating Loss for the Year		396,685
	Other Charges—		
58,772	Interest on Capital	60,102	
28,283	Depreciation	29,109	
6,711	Superannuation—Employers Share	7,369	
93,766			96,580
486,784	Total Loss for the Year		493,265

BALANCE SHEET AS AT 31st DECEMBER, 1968

31st December, 1967	Funds Employed	31st December, 1968	
$		$	$
	Capital—		
1,402,051	Provided from General Loan Fund	1,431,595	
274,409	Provided from Consolidated Revenue Fund	274,409	
1,676,460			1,706,004
	Reserves—		
57,244	Commonwealth Grant—Assistance to Gold Mining Industry	57,244	
27,572	Commonwealth Grant—Assistance to Metalliferous Mining	27,572	
84,816			84,816
	Liability to Treasurer—		
2,329,883	Interest on Capital		2,389,984
10,000	Advance for Purchase of Tailings		....
	Other Funds—		
5,269,784	Provided from Consolidated Revenue Fund (Excess of payment over collections)		5,666,446
9,370,943			9,847,250
	Deduct—		
	Profit and Loss:		
8,559,707	Loss at Commencement of Year	9,046,491	
486,784	Loss for Year	493,265	
9,046,491	Total Loss from Inception		9,539,756
324,452			307,494
	Employment of Funds		
	Fixed Assets—		
1,665,278	Plant, Buildings and Equipment	1,694,822	
1,424,208	Less Depreciation	1,453,317	
241,070			241,505
	Current Assets—		
8,740	Debtors	13,406	
76,226	Stores	82,757	
9,986	Battery Spares	9,571	
	Purchase of Tailings:		
21,758	Treasury Trust Account	16,146	
86,996	Tailings not treated	81,603	
12,637	Estimated Gold Premium	12,232	
216,343			215,715
457,413	**Total Assets**		457,220
	Deduct—		
	Current Liabilities:		
23,702	Creditors	34,508	
93,868	Liability to Treasurer (Superannuation—Employers Share)	101,237	
	Purchase of Tailings:		
2,754	Creditors	1,749	
12,637	Estimated Premium Due	12,232	
132,961			149,726
324,452			307,494

DIVISION IV

Annual Report of the Geological Survey Branch of the Mines Department for the Year 1968

CONTENTS

REPORTS

LIST OF PLATES

LIST OF FIGURES

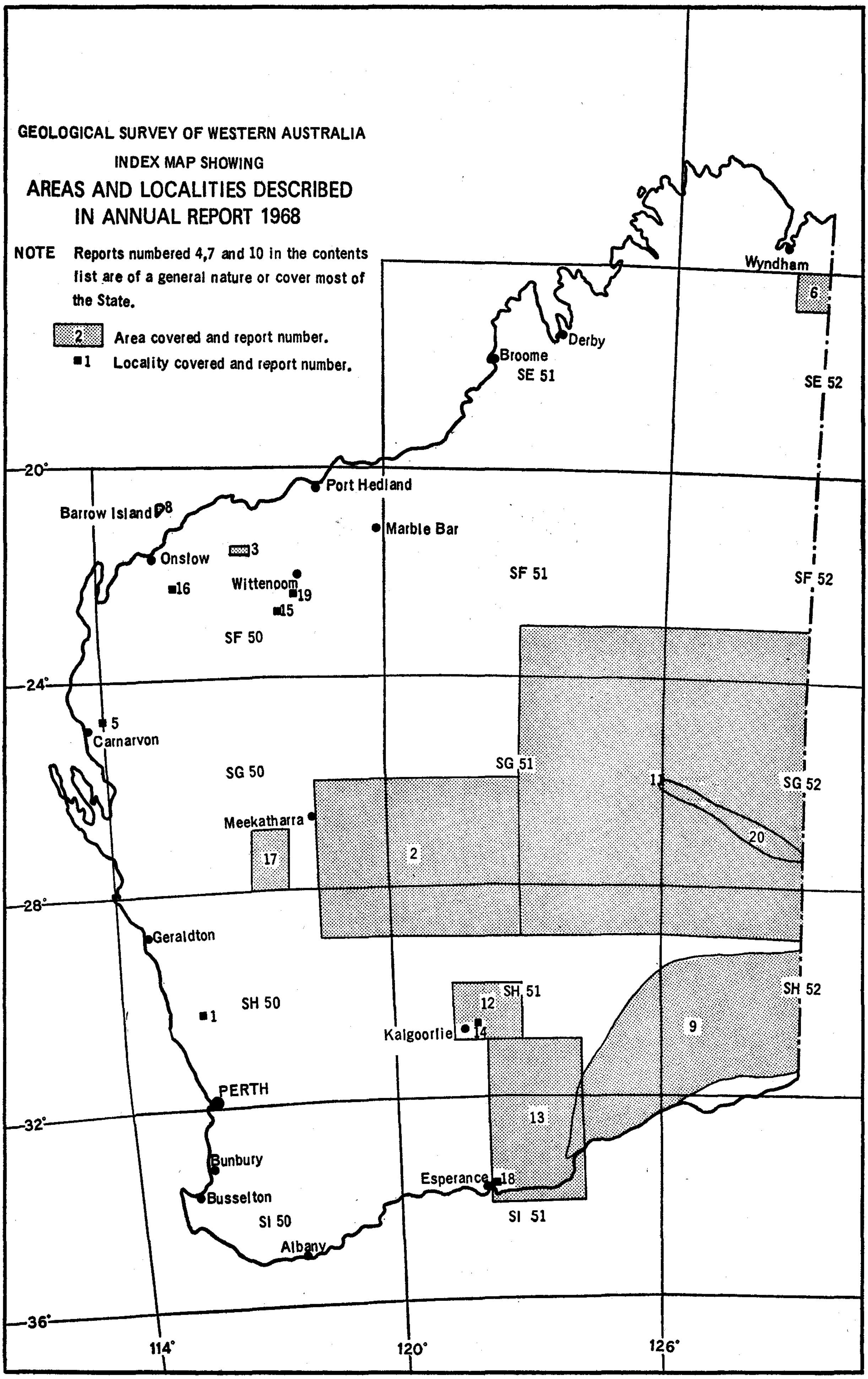
GEOLOGICAL SURVEY OF WESTERN AUSTRALIA
INDEX MAP SHOWING
AREAS AND LOCALITIES DESCRIBED IN ANNUAL REPORT 1968
NOTE Reports numbered 4,7 and 10 in the contents list are of a general nature or cover most of the State.
2 Area covered and report number.
1 Locality covered and report number.
Wyndham
6
Derby
Broome
SE 51
SE 52
20°
Port Hedland
Barrow Island 8
Marble Bar
Onslow
3
16
Wittenoom
19
15
SF 50
SF 51
SF 52
24°
5
Carnarvon
SG 50
SG 51
SG 52
11
20
Meekatharra
17
2
28°
Geraldton
SH 50
SH 51
SH 52
12
1
Kalgoorlie
14
9
PERTH
32°
13
Bunbury
Esperance
18
Busselton
SI 50
SI 51
Albany
36°
114°
120°
126°

FIGURE 1

DIVISION IV

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Annual Report of the Geological Survey Branch of the Mines Department for the Year 1968

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The Under Secretary for Mines

For the information of the Honourable Minister for Mines, I submit my report on the activities of the Geological Survey of Western Australia for the year 1968, together with some of the reports on investigations made for departmental purposes.

INTRODUCTION

The exploration boom in this State continued during 1968 and shows no sign as yet of slackening. Very few companies have reduced their activity while others are still establishing themselves.

Nickel continues to be the mineral most sought although some exploration companies are turning to other base metal and uranium possibilities.

The presence of a nickel ore body has been established at Scotia, 40 miles north of Kalgoorlie, while the investigation of nickel mineralization is continuing in the Mt. Martin, St. Ives, Widgiemooltha, Higginsville and Nepean areas to ascertain if mining is warranted.

A copper ore body which has been located at Mons Cupri near Whim Creek is still being evaluated. The testing and feasibility study on the bauxite near Admiralty Gulf has been completed and the company concerned has signed an agreement with the Government to proceed. An iron ore occurrence discovered several years ago at Paraburdoo was tested and proved to be high grade and of major dimensions.

There was an oil flow of interest in the Legendre No. 1 offshore well, some 70 miles north of Roebourne, while further significant gas was found south of Dongara in the Mondarra No. 1 well.

The continued unparalleled exploration activity in this State has maintained a great demand on the services of this Branch. The professional advice of the staff is continually sought by companies. The reference library, card indexes, and open files are being consulted continuously by those engaged in the search for minerals. The sale of Geological Survey publications increased from $4,500 in 1967 to $8,900 in 1968, which is eleven times greater than in 1963. The demand for all services has increased immensely.

Because of the company activity on mineral deposits the Survey has been able to accelerate the programme of regional mapping. At the end of 1968, mapping of 53 per cent. of the 178 1 : 250,000 sheets covering the State had been commenced while 34 per cent. of the sheets are available in a preliminary or published form, compared with 13 and 11 per cent. respectively in 1960. The co-operation of the Bureau of Mineral Resources in the Kimberley Division with joint field parties, and with printing of maps, is gratefully acknowledged.

The exploration companies are particularly interested in the results of regional mapping carried out by geologists of the Survey. However, after the completion of the field work there is a frustrating delay of at least two years while the map is compiled, drafted and published in the 1:250,000 geological series. In an attempt to relieve this situation, a lecture and two-day field excursion was arranged on the Kurnalpi sheet when the field work was completed, as an experiment to ascertain if this would assist the exploration companies. The attendance of 135 at the lecture in Kalgoorlie and of over 90 on the excursion showed that field geologists were keenly interested and there were requests for similar projects on other sheets,

Later in the year a similar project was carried out on the Menzies 1 : 250,000 sheet and again 125 attended the lecture and 72 the two-day excursion.

The success of these two ventures has proved that this is a suitable way of presenting results of mapping to interested persons while awaiting the publication. It is the Survey's intention to continue this service as suitable sheets are mapped and while the demand continues.

ACCOMMODATION

As the construction of Mineral House has commenced, the Survey anticipates having adequate and suitable accommodation by the end of 1969.

During this year the extension to the Dianella Core Library was completed, which greatly eased the storage situation until the transfer of a large quantity of drill core from the State Mining Engineers Branch used a consderable amount of the new space.

The sketch plans for the new equipment store and vehicle park have been completed and it is hoped that it will be built during the first half of 1969.

By the end of 1969 the accommodation and storage situation of the Survey should be adequate to cope with present requirements.

STAFF

Although the Survey has had up to to ten professional vacancies during 1968, the situation has improved toward the end of the year. There are only two vacancies remaining to which a suitable officer has not yet been appointed.

Of the eleven appointments made this year, nine were from overseas. It appears that while the current boom continues it will be necessary to rely on overseas sources for professional staff.

During the year six geologists resigned, mainly to accept more lucrative positions, and two more intend to resign early in the new year.

A Doctorate of Philosophy from the University of Western Australia was conferred on a member of staff, J. R. Passmore, for his hydrogeological research on the aquifers in the Rockingham area.

Dr. A. F. Trendall was awarded a Churchill Scholarship to study varved rocks in various parts of the world for comparison with the varving in the Precambrian banded iron formation of the Hamersley Range.

The establishment of the Branch is now 49 professional, 6 clerical, and 12 general officers.

PROFESSIONAL

Appointments

Name	Positions	Effective Date
W. A. Davidson, B.Sc.	Geologist, Grade 2	1/2/68
P. R. Koehn, B.Sc. (Hons.)	Geologist, Grade 2 (Temp.)	12/3/68
R. Peers, B.Sc. (Hons.)	Geologist, Grade 2 (Temp.)	29/5/68
B. R. Paterson, B.Sc.	Geologist, Grade 2	19/7/68
X. K. Williams, M.Sc.	Geochemist	19/8/68
J. D. Lewis, B.Sc.	Geologist, Grade 2	23/9/68
J. Newton-Smith, M.Sc.	Geologist, Grade 2	29/10/68
D. D. Boyer, B.Sc. (Hons.)	Geologist, Grade 2	11/11/68
J. Backhouse, M.Sc.	Geologist, Grade 2	26/11/68
A. S. Harley, B.Sc. (Hons.)	Geologist, Grade 2	3/12/68
J. C. Barnett, B.Sc. (Hons.)	Geologist, Grade 2	16/12/68

Resignations

L. N. Wall	Geologist, Grade 2	15/3/ 89
R. Lake	Geologist, Grade 2 (Temp.)	31/1/68
R. Peers	Geologist, Grade 2	9/1/68
D. H. Probert	Geologist, Grade 1	25/3/68
R. A. Farbridge	Geologist, Grade 2	26/7/68
H. Rutter	Geophysicist, Grade 2	2/8/68
M. J. B. Kriewaldt	Geologist, Grade 1	7/9/68

CLERICAL AND GENERAL

Appointments

H. F. Rettig	Core Librarian	27/5/68
J. M. Dyer	Stores and Transport Clerk	18/3/68
G. A. Squires	Laboratory Assistant	16/10/68

Resignations

H. F. Rettig	Core Librarian	15/3/68
R. J. Sorensen	Laboratory Assistant	28/6/68

Transfers

R. A. H. Stevenson	Clerk	15/11/68

OPERATIONS

HYDROLOGY AND ENGINEERING GEOLOGY DIVISION

E. P. D. O'Driscoll (Chief Hydrogeologist), K. Berliat, F. R. Gordon, T. T. Bestow (Senior Geologists), K. H. Morgan, J. R. Passmore, P. Whincup, C. C. Sanders, P. M. Hancock, W. A. Davidson, D. D. Boyer, A. S. Harley, J. G. Barnett, A. D. Allen (on leave without pay at London University), and R. S. Chaturvedi (Colombo Plan Fellow).

Hydrology

Exploratory rotary and percussion drilling has continued in the sediments of the Coastal Plain Basin west of Watheroo, in the search for additional groundwater for the Northern Comprehensive Water Supply Scheme. Work is expected to be completed early in 1969, and substantial reserves of potable water have been proved.

A further six exploratory bores have been drilled west of Albany in the Werillup area and have confirmed the low groundwater potential indicated by previous work.

To meet the demand for large supplies of water for industrial use at the new port of Dampier a hydrological investigation was made of an extensive area of calcrete at Millstream on the Fortescue River. Twenty-five boreholes were drilled and a comparatively large amount of usable water was located.

Drilling and test pumping shallow sand aquifers east of Lake Gnangara for the Metropolitan Water Board has continued. Advice has been given to the Board on future exploratory drilling in the new suburb of Hamersley and the North Lake Gnangara area.

A field reconnaissance of the calcreted drainages in the East Murchison District indicates that in the north some areas are fairly good potential sources of potable water, but rapidly become less valuable to the south.

Three calcrete areas near Cue have been test pumped as part of an arid zone research project. One bore was pumped at 125,000 gallons per hour, the highest rate yet achieved anywhere in the State from a shallow bore. Work on the hydrology of the Cue 1 : 250,000 geological sheet has continued.

Bore census work has been undertaken in a number of areas, one being Bunbury township, where the establishment of a net of observation bores has been recommended for future use in the assessment of over-pumpage.

Field hydrogeological surveys have also been made for the townships of Port Gregory, Ravensthorpe, Nabawa, Cervantes, Ledge Point, Horrocks Beach, Carnamah, Calingiri, Greenough River Mouth, Halls Creek, Bindi Bindi, Cranbrook, Mt. Tom Price, and on the North Lake Grace—Kulin areas. Properties inspected for private landholders numbered 164, including 17 in Kimberley Division, and advice was given on the prospects of obtaining underground water. Compilation of bore records throughout the State has continued.

Engineering geology

The Stonewall Creek spillway for the Ord River dam was mapped in detail, diamond drilling of the spillway, the river bed, and the proposed quarry areas supervised and reported on, and geological advice given to the designing engineers and also construction firms tendering for the work. Preliminary investigations of damsites on the Gascoyne River are complete and reports on the geology of the sites, and the area in general, have been prepared.

At the request of other Government Departments, twelve possible damsites have been the subject of written reports, another nine have been given a preliminary examination or a follow-on inspection. Detailed geological assessments of two more are almost complete, and field advice has been given to engineering construction teams on two others.

Subsequent to the Meckering earthquake, the nature and extent of the faulting and its associated effects have been investigated in some detail.

SEDIMENTARY (OIL) DIVISION

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

During 1968 this Division was occupied to an increasing degree in the collation and appraisal of oil exploration and production data. A report was completed for departmental purposes on the Dongara gas field and an appraisal of the Barrow oilfield is in progress.

The mapping of the Phanerozoic portion of the Geraldton 1 : 250,000 sheet has been completed while mapping of the Moora and Hill River sheets in the Perth Basin is near completion. A report on the geology of the Moora Group is in preparation.

A detailed stratigraphic and palaeontological study of the Bugle Gap area in the Canning Basin was initiated during the year. The field work for the project is now complete.

The bulletin on the Eucla Basin is in preparation and the compilation of the 1 : 250,000 sheets of the basin is almost complete.

Remapping of the metropolitan area in association with the Regional Geology Division was completed and the four 1 : 50,000 sheets are being drawn for publication.

REGIONAL MAPPING DIVISION

R. C. Horwitz (Supervising Geologist), J. L. Daniels (Senior Geologist), I. R. Williams, J. J. G. Doepel, and P. R. Koehn.

Eastern Goldfields area

Geological mapping was completed on the Kurnalpi, Menzies, Zanthus, Balladonia and Malcolm 1 : 250,000 sheets which are now being compiled. Compilation is continuing also on the Esperance, Mondrain Island, and Cape Arid sheets, which were mapped in association with the Hydrology Division.

GEOLOGICAL SURVEY OF WESTERN AUSTRALIA

1 250,000 OR 4 MILE GEOLOGICAL MAPPING

1968

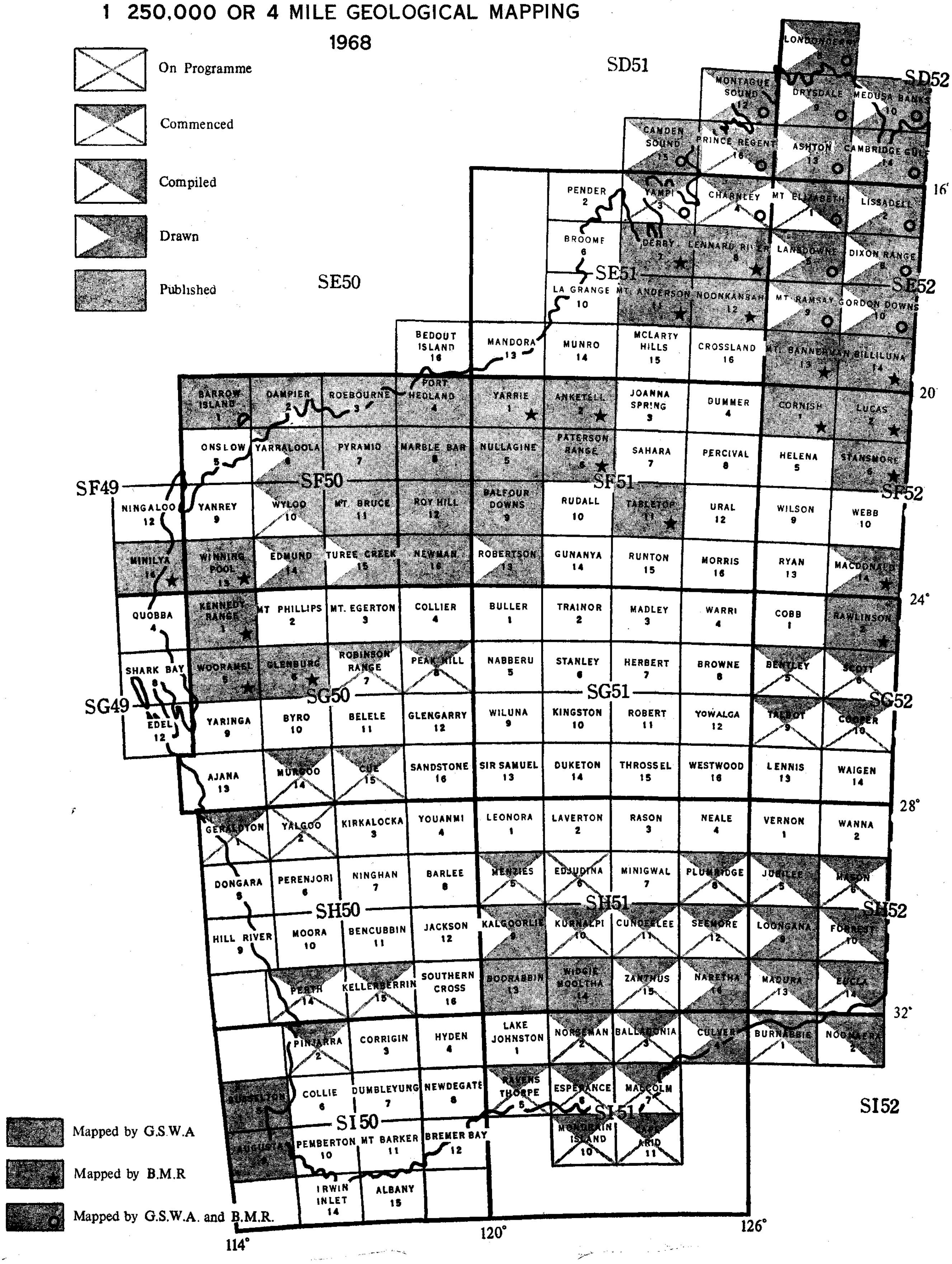


FIGURE 2

Geological mapping was commenced on the Norseman 1 : 250,000 sheet.

A lecture followed by a two-day field excursion was given on the geology of the Kurnalpi sheet to acquaint geologists with the results of the mapping. This was later repeated for the Menzies sheet.

Blackstone—Warburton area

Geological mapping of the Talbot 1 : 250,000 sheet was completed and compilation of the Talbot, Bentley, Scott and Cooper sheets is nearing completion. A detailed study of the geology of this area is being made in preparation for a Bulletin.

North-West Division

Geological mapping of Peak Hill 1 : 250,000 sheet was completed and compilation is in progress. Mapping has commenced on Robinson Range. The compilation of Wyloo and Edmund was completed.

General

To assist with the investigation of the earthquake, geological mapping in the Meckering region on the Kellerberrin 1 : 250,000 sheet was completed and is being compiled.

The mapping of the Precambrian portion of the Geraldton 1 : 250,000 sheet is almost completed and compilation has commenced.

The progress of geological mapping at 1 : 250,000 scale to the end of 1968 is shown in Figure 2.

MINERAL RESOURCES DIVISION

L. E. de la Hunty (Supervising Geologist), J. Sofoulis (Senior Geologist), J. G. Blockley, P. C. Muhling, J. L. Baxter, and J. Newton-Smith.

Kimberley Division

Record compilations on the Yampi 1 : 250,000 sheet area and on the Pillara Range Inlier of the Noonkanbah 1 : 250,000 sheet area were completed as part of the Kimberley Mapping Project.

North-West Division

Field work was completed on the mineral resources, regional geology, and hydrology of the Cue and Murgoo 1 : 250,000 sheet areas. Record reports on both areas are in preparation.

Diamond drilling programmes at Thaduna and Green Dragon copper mines were supervised for British Metal Corporation.

General

A detailed geological investigation supported by geophysical and geochemical work was completed on Ministerial Reserve 4538H at Lake Yindarlgooda, Bulong District east of Kalgoorlie.

Approximately 160 prospects in the Pilbara, Kimberley, Ashburton, and Northampton areas were inspected in the course of preparing a Mineral Resources Bulletin on silver-lead-zinc deposits of the State.

Tin deposits in the Kimberley and Pilbara Goldfields were investigated for eventual compilation of a Mineral Resources Bulletin on the State's tin deposits.

Other miscellaneous investigations during 1968 included inspections of copper, nickel, asbestos, and clay prospects.

COMMON SERVICES DIVISION

Petrology (A. F. Trendall, J. D. Lewis, and R. Peers)

Petrological work during 1968 did not involve the initiation of any new major projects, but consisted largely of the provision of service to the Divisions of the Geological Survey, in the form of unpublished reports and advice by personal discussion. Twenty file reports were written, fewer than in immediately preceding years; the decrease reflects partly changes in staff, partly greater detail in the content of reports, and partly a continued policy of encouraging field staff to use the microscope wherever possible. A total of 1,170 thin-sections and 52 polished sections were prepared by the laboratory staff.

Dr. Trendall visited the Warburton—Blackstone area in July and the Hamersley Range area in August.

During 1968 the liaison that had been established in preceding years with the Geophysics Department of the Australian National University for geochronology work on the Precambrian rocks of the State continued; a similar arrangement was also initiated with the Physics Department of the Western Australian Institute of Technology, in which their mass spectrometer and X-ray fluorescence spectrometer will be used on rocks and minerals collected for geochronological study by the Survey and supplied in powder or concentrate form. This work should usefully augment that of the Australian National University, and will be the first use of the rubidium-strontium method in Australia outside Canberra for some years.

Mineralogical and chemical work at the Government Chemical Laboratories again provided a useful complement to some of the petrological work carried out, and is acknowledged with gratitude.

Palaeontology (A. E. Cockbain, B. S. Ingram, and J. Backhouse)

In 1968 fifty-eight file reports were written. These included studies of Cretaceous palynomorphs in the northern Perth Basin and Eucla Basin, Miocene nautiloids from the Eucla Basin, Devonian brachiopods from the Lennard Shelf, and examination of various Tertiary palynomorphs and microfossils from the Denmark—Esperance area. Most of the reports were in the field of palynology and were written for the Hydrology Division.

Reports written for	Field of Palaeontology		
	Palynology	Micropalaeontology	Macropalaeontology
Hydrology/Engineering	30	6	....
Sedimentary (Oil)	8	2	2
Regional Mapping/Mineral Resources	2	....	1
Miscellaneous	5	1	1

Additional to these reports and in order to provide geologists in the Hydrology Division with information as rapidly as possible, a new series of Palaeontological Notes was instituted. These give the results of a preliminary examination of important samples; some 34 such notes were written.

Dr. Cockbain is continuing work on Tertiary fossils from the Eucla Basin with a study of the systematics of Cheilostomatous Bryozoa from the Eucla, Eundynie, and Plantagenet Groups. He spent three months in the Bugle Gap area (Kimberley Division) with Dr. Playford, assisting in the detailed biostratigraphical and palaeoecological examination of the Devonian reef complexes.

As well as attending to the routine examination of borehole samples, Mr. Ingram is continuing his work on the systematic and stratigraphical palaeontology of Lower Cretaceous palynomorphs from the Perth Basin. In July he accompanied Dr. Macurda of the University of Michigan in the field to the classical Permian locality at Callytharra Springs.

We are grateful to Dr. B. E. Balme (University of Western Australia) and Mr. G. W. Kendrick (Western Australian Museum) for their help in examining certain samples.

Geophysics (D. L. Rowston and H. Rutter)

The demand for well-logging services again showed a substantial increase over the previous year, and logging operations involved more than 17,000 miles of travel. Logging statistics are tabulated below:

	1968	1967	1966
Individual bores	80	42	26
Logging operations	99	72	35
Logged footage	73,350	51,700	38,000
Footage of final logs to total depth	52,600	29,600	N.A.*
Reports compiled	29	12	8

* Figure not available.

On the deeper bores intermediate logs are made and the logged footage, by including these intermediate logs, is higher than the footage of final logs to total depth. Also one logging operation may involve several runs into the hole to measure different parameters; the logged footage does not include individual runs and another 29,000 feet could be added to the 1968 total footage to account for this factor.

Field salinity measurements were made on 722 water samples received in the laboratory. Laboratory facilities have been extended to include magnetic susceptibility measurements and rock densities, and these properties were determined for 322 core samples from the Upper Mantle Project diamond drill holes.

A gravity survey was carried out in the Millstream area to assist hydrogeological investigations, but the environment proved to be more complicated than anticipated and an acceptable interpretation of the results appears unlikely.

Magnetic, electromagnetic, self-potential, and gravity methods were used on Ministerial Reserve 4538H, northeast of Kalgoorlie, in the exploration for base metal sulphides.

Geochemistry (X. K. Williams)

Geochemical work within the Survey commenced at the end of August with the appointment of a geochemist.

A study was made of an extensive gossan in Ministerial Reserve 4538H; the results of this work are discussed later.

Plans were made to build a mobile field laboratory caravan and equip it for routine trace element analyses by atomic absorption spectroscopy. It is hoped that this will be ready for use during the 1969 field season.

Technical Information (R. R. Connolly, M. E. Redman, and S. M. Fawcett)

The resources of the section have again been strained by increasing requests for released information, advice, and specimen identifications, but a satisfactory service was maintained.

Library loans to staff totalled 2,333 and loans to other than staff 806. The number of visitors using the library doubled, and this, together with the natural increase in book stock, resulted at times in severe overcrowding and difficult working conditions.

Requisitions to the Survey and Mapping Branch for drafting services and photocopying totalled 1,207 which is also a significant increase. Three publications were edited, printed and distributed and several other publications are at intermediate stages of printing. Twenty-two Records were prepared, duplicated, and assembled and, as one particular issue required 900 copies, this became a major task.

Considerable time was spent planning the detailed layout of the three floors to be occupied by this Branch in Mineral House.

ACTIVITIES OF THE COMMONWEALTH BUREAU OF MINERAL RESOURCES

The geological and geophysical projects carried out by the Bureau of Mineral Resources included the following:

(1) Compilation of 1 : 250,000 geological maps and bulletins on the Kimberley Division as a joint project with this Survey.

(2) An examination of the conodonts in the Bugle Gap area of the Canning Basin in conjunction with Survey's studies.

(3) Aeromagnetic and radiometric survey of the Sandstone and Youanmi 1 : 250,000 sheets at 1 mile spacings.

(4) Regional helicopter gravity survey of a large area of the North-West and Canning Basin.

PROGRAMME FOR 1969

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) Watheroo—Agaton area (continuation)
   (b) Albany (continuation)
   (c) Lake Gnangara (continuation)
   (d) Mandurah—Pinjarra (continuation)
   (e) Wiluna district
   (f) Esperance for industrial supplies
   (g) Port Hedland
   (h) Others may be added.
3. Kimberley—hydrological assistance to pastoralists.
   (a) bore site selection as required
   (b) completion of compilation of hydrogeological mapping in conjunction with the Bureau of Mineral Resources.
4. Continuation of bore census work in selected areas.
5. Miscellaneous investigations as requested by other Government departments and the public.

Engineering

1. Ord River Dam—geological supervision during construction (if staff available).
2. Helena River Dam Site—detailed investigation of site near Piesse Brook.
3. North and South Dandalup Dam Sites—further investigation.
4. Pilbara—further investigation of possible dam sites.
5. Moochalabra Creek dam site—supervision of construction.
6. Meckering earthquake—completion of investigation and compilation of report.
7. Other dam site investigations for Public Works Department, if staff available.

SEDIMENTARY (OIL) DIVISION

1. Maintain an active interest in the progress and assessment of oil exploration in Western Australia.
2. Assessment of the oil and gas discoveries, and assessment of resources in the State.
3. Continuation of the mapping programme in the Perth Basin.
4. Continuation of the detailed biostratigraphic study of material collected at Bugle Gap.
5. Miscellaneous investigations as required.

REGIONAL GEOLOGY DIVISION

1. Continuation of the mapping of the Norseman 1 : 250,000 sheet.
2. Complete compilation of Balladonia, Malcolm, Zanthus, Kurnalpi, and Menzies 1 : 250,000 sheets.
3. Commence mapping the Edjudina 1 : 250,000 sheet in the Eastern Goldfields.
4. Commence mapping the Robinson Range 1 : 250,000 sheet.

MINERAL RESOURCES DIVISION

1. Continuation of the mineral survey of the Yalgoo and Murchison Goldfields.
2. Completion of a Mineral Resources Bulletin on the silver-lead-zinc deposits of Western Australia.
3. Preparation of a Mineral Resources Bulletin on the tin deposits of Western Australia.
4. Detailed investigation including geochemical work of the Twin Peaks copper prospect.
5. Detailed investigation of the Robinson Range Iron deposit.
6. Miscellaneous investigations as required.

PUBLICATIONS AND RECORDS

Issued during 1968

Annual Report 1967.

Geological map of Pyramid 1 : 25,000 Sheet (SF/50-7 International Grid) with explanatory notes.

Geological map of Busselton and Augusta Sheets (SI/50-5 and SI/50-9 International Grid) with explanatory notes.

In press

Report 1, Devonian carbonate complexes of Alberta and Western Australia, a comparative study.

Geological map of Yarraloola 1 : 250,000 Sheet (SF/50-6 International Grid) with explanatory Notes.

Geological map of Turee Creek 1 : 250,000 Sheet (SF/50-15 International Grid) with explanatory notes.

Geological map of Edmund 1 : 250,000 Sheet (SF/50-14 International Grid) with explanatory notes.

Geological map of Robertson 1 : 250,000 Sheet (SF/51-13 International Grid) with explanatory notes.

Geological map of Kalgoorlie 1 : 250,000 Sheet (SH/51-9 International Grid) with explanatory notes.

In preparation

Bulletin 119, Iron formations of the Precambrian Hamersley Group, Western Australia with special reference to the associated crocidolite.

Bulletins are being prepared on the Eucla Basin; Blackstone Range Area; silver-lead-zinc deposits of Western Australia; and Devonian coral faunas of the Canning Basin.

Geological maps 1 : 250,000 with explanatory notes, the field work having been completed: Wyloo, Kurnalpi, Menzies, Peak Hill, Cue, Murgoo, Scott, Cooper, Bentley, Talbot, Culver, Naretha, Madura, Loongana, Jubilee, Noonaera, Eucla, Forrest, Esperance—Mondrain Island, Zanthus, Balladonia, and Malcolm—Cape Arid.

Geological maps 1 : 50,000 Perth metropolitan area (4 sheets).

Records produced

1968/1 Erosion at Bandicoot Bar diversion dam, Kimberley Division, by F. R. Gordon (*restricted*).

1968/2 The geology of the Ord River dam and associated works, by F. R. Gordon, with supplements 1 and 2 (*restricted*).

1968/3 Explanatory notes on the Edmund 1 : 250,000 geological series sheet SF/50-14, Western Australia, by J. L. Daniels.

1968/4 Geology of the area around the Kennedy Range dam site, by J. L. Baxter (*restricted*).

1968/5 Preliminary hydrologic report on the Moora Group, by L. N. Wall.

1968/6 The hydrology of the Scott, Cooper Bentley, and Talbot 1 : 250,000 Sheets, by R. A. Farbridge.

1968/7 Hydrogeology of the lower Gascoyne River, by J. L. Baxter.

1968/8 Geological reconnaissance of Cooya Pooya dam site, Harding River, by F. R. Gordon (*restricted*).

1968/9 Explanatory notes on the Wyloo 1 : 250,000 geological sheet, by J. L. Daniels.

1968/10 The geology of the Pillara Range Precambrian inlier, Noonkanbah 1 : 250,000 sheet, by J. Sofoulis and D. C. Gellatly.

1968/11 Lower Gascoyne River, possible flow losses downstream from Kennedy Range dam site, by J. R. Passmore.

1968/12 Geological investigations at Rocky Pool dam site in 1967, by P. M. Hancock (*restricted*).

1968/13 Review of grouting procedures, Ord River Main Dam, by F. R. Gordon (*confidential*).

1968/14 Reconstruction of Meckering town a geological appraisal, by F. R. Gordon.

1968/15 Dongara gas field estimates of reserves and economics of piping gas to Geraldton and Perth, by A. H. Pippet (*confidential*).

1968/16 Explanatory notes on the Culver 1 : 250,000 geological sheet, SI/51-4, Western Australia, by D. C. Lowry.

1968/17 Report on Ministerial Reserve 4538H, Lake Yindarlgooda, Bulong District, Western Australia, by J. Sofoulis, X. K. Williams, and D. L. Rowston.

1968/18 Wells drilled for petroleum exploration in Western Australia in 1968, by P. E. Playford and G. H. Low.

1968/19 Petrology and metamorphism in the Fraser Ranges, by P. R. Koehn.

1968/20 The hydrogeology of the Tumblagooda Sandstone near Horrocks Beach and Port Gregory, by P. Whincup.

1968/21 Groundwater prospects in the Mallee Districts, Esperance 1 : 250,000 sheet, by C. C. Sanders.

1968/22 Nooka Lead Mine—M.L. 284—Northampton Mineral Field, by J. G. Blockley.

Reports in other publications

Cockbain, A. E. 1968, Distribution of the nautiloid *Aturia* in the Eocene: Jour. Palaeont, v. 42, p. 1309.

McCall, G. J. H., Braybrooke, J. C., Middleton, D. D., and Muhling, P. C., 1967, Sedimentology of some eugeosynclinal rocks of the early Precambrian Kalgoorlie System, Western Australia: International Sedimentological Congress, 7th.

Trendall, A. F., 1968, Three great basins of Precambrian banded iron formation deposition: a systematic comparison; Geol. Soc. America Bull. v. 79, p. 1527-1544.

Lowry, D. C., 1967, Halite speleotherms from the Nullarbor Plain, Western Australia: Helictite, v. 6, No. 1, p. 14-20.

22nd January, 1969

J. H. LORD,
Director,
Geological Survey.

EXPLORATORY DRILLING – AGATON PROJECT, WATHEROO AREA PRELIMINARY REPORT

by J. R. Passmore

INTRODUCTION

Groundwater resources of part of the Perth Basin are being investigated by drilling in the Watheroo area, about 140 miles north of Perth. A supply of 5 million gallons per day is required for distribution to towns in agricultural country to the east. The project, which takes its name from a spring in the southern part of the area (Plate 1), is an extension of a drilling programme comprising a a line of exploratory bores west from Watheroo (Bores WL1 to WL4). Investigations are not yet complete, and interpretations may be modified later.

Including the Watheroo line of bores, 26 sites have been drilled, the total footage being 41,390 feet, of which 30,435 feet were drilled with rotary and 10,955 feet with percussion rigs. Most bores were completed with screens or slotted casing and eight were test-pumped for at least 48 hours.

A summary of data from the bores is presented in Table 1.

GEOLOGY

The drilled area is in the northern half of the Perth Basin, a sedimentary trough over 400 miles long on the western side of the Western Australian Precambrian Shield. The Darling Fault Zone forms the eastern margin of the basin and in the Watheroo area separates the basin sediments from jointed quartzite and chert of the Moora Group.

The sediments penetrated by the bores are of Cretaceous age, overlain in some places by superficial Quaternary sand. They are commonly weathered, leached, or lateritized near the surface. The following units are recognized:

Upper Cretaceous marine formations (Ku) comprise the Poison Hill Greensand, Gingin Chalk, Molecap Greensand, and Osborne Formation. The Osborne Formation has been dated as Albian—Cenomanian and the others as Senonian. The sequence consists of green glauconitic sandy clay and silt with minor grey calcareous siltstone; formation boundaries within it are seldom distinct.

Marine member of the South Perth Formation (Klsa) is of Lower Cretaceous age, and consists of green and grey glauconitic sandstone and siltstone overlying the rest of the South Perth Formation. It forms a distinctive marker bed over the eastern part of the area, and has been dated as Neocomian—Aptian on fossil microplankton.

South Perth Formation (Kls) is also of Lower Cretaceous age, being predominantly grey and greenish sandstone, siltstone, and shale of non-marine origin, some parts well-bedded and others poorly bedded. The beds are lenticular, and it is often difficult to correlate between bores three or four miles apart. The well-bedded sandstones are predominantly coarse-grained and moderately well-sorted.

The three units appear to be separated by disconformities, although detailed correlations could show up angular unconformities. In some places either the Osborne Formation or the marine member of the South Perth Formation is overlapped by younger beds, indicating non-deposition or erosion during Cretaceous times.

Over most of the area the beds strike north and dip to the east at one to three degrees (see Plate 1). Near the eastern edge of the basin they are either synclinal or faulted, as the section in Bore WL1 is displaced upwards relative to that in Bore A19. The anticline near the western end of the section is based on correlations between Bores WL3, WL4, and others north of the section, although it is possible that the strata are faulted. Faulting may explain the lack of correlation between Bore A7 and A24-WL2, but as yet there is no confirmatory evidence.

HYDROLOGY

Aquifers

The superficial Quaternary deposits are too thin to warrant large scale development, although in some places they do provide stock water supplies. There are thin aquifers within the Upper Cretaceous sediments, containing only salty water.

Aquifers within the South Perth Formation and its marine member are capable of yielding large supplies of water. They are lightly consolidated sandstones of variable grain size, sorting, and silt content. These properties change laterally and the best aquifers occur at different stratigraphic levels, but generally in the upper 1,000 feet of the South Perth Formation. The marine member of the South Perth Formation is in most places medium-grained and fairly well sorted, and is therefore moderately permeable.

The most promising area for groundwater development is the central to eastern part, because farther westward only the lower, less permeable, part of the formation is intersected.

Bore yields

Bores were generally completed with five-inch screens or six-inch slotted casing, and most of those capable of yielding large supplies were test-pumped for at least 48 hours. Several were abandoned because of technical difficulties. The results of pumping 10 bores, listed in Table 1, indicate that bores with slotted casing gave the largest supplies, up to 20,000 gallons per hour. This resulted from the slotted sections tapping several aquifers and the total thickness of the production zones being greater than in the screened bores. Test-pumping rates were less than the maximum, and the small drawdowns in Bores A12, A13, A16, and A17 indicate that much larger supplies are available. Transmissivity values listed in Table 1 were calculated from drawdown and recovery measurements in the pumped bores. They ranged widely, from 880 to 12,800 ft²/day, partly because of the different thicknesses of the production zones.

TABLE 1.

AGATON PROJECT BORE DATA

Bore No.	Depth drilled	STRATIGRAPHY				Production zones	Screen (S) or slotted casing (Sc)	Total screened or slotted	Pump test	Pumping rate	D/down after 48 hrs.	Calculated transmissivity	S.W.L. below ground surface	Salinity prod. zones	Status
		Q	Ku	Klsa	Kls										
	ft *	ft	ft	ft	ft	ft		ft	hrs	gph	ft	ft/day	ft	ppm	
A1	1773 R	....	....	....	0–1773	460–760	Sc	....	....	....	....	....	210	1000	Obs
A2	233 P	0–76	....	....	76–233	....	....	....	....	....	....	....	....	....	Abd
A2a	1000 P	0–76	....	....	76–1000	....	....	....	....	....	....	....	....	....	Abd
A3	2320 R	....	0–319	319–480	480–2320	381–752	Sc	86	48	15,000	105	880	98	430	Obs
A4	556 P	....	....	....	0–556	536–548	S	12	24	8,700	....	....	253	700	Abd
A5	1000 P	....	0–318	318–538	538–1000	430–743	Sc	133	....	....	....	....	181	980	Obs
A6	594 P	....	....	....	0–594	570–594	S	24	24	7,600	....	....	204	500	Obs
A7	1000 P	....	....	....	0–1000	666–696	S	30	48	11,000	123	1,500	147	570	Obs
A9	890 R	....	0–652	....	652–890	....	....	....	....	....	....	....	....	....	Abd
A9a	1800 R	....	0–652	....	652–1800	779–787	S	8	....	....	....	....	207	1000	Obs
A10	1000 P	....	....	....	0–1000	590–650	Sc	60	....	....	....	....	180	480	Obs
A11	623 P	....	....	....	0–623	....	....	....	....	....	....	....	252	....	Obs
A12	2325 R	....	....	....	0–2325	824–1104	Sc	120	48	19,000	26·4	6,400	202	480	Obs
A13	1024 P	....	0–475	475–697	697–1024	668–698	S	30	48	18,200	40	2,330	113	740	Obs
A14	1000 P	....	0–590	....	590–1000	854–865	S	11	....	....	....	....	197	1170	Obs
A15	2410 R	....	....	....	0–2410	....	....	....	....	....	....	....	....	....	Abd
A15a	547 R	....	....	....	0–547	410–530	Sc	80	....	....	....	....	247	....	Obs
A15b	592 R	....	....	....	0–592	416–546	Sc	85	67	11,000	86	1,200	246	500	Obs
A16	1465 R	....	0–70	70–150	150–1465	....	....	....	....	....	....	....	....	....	Abd
A16a	400 R	....	0–70	70–150	150–400	....	....	....	....	....	....	....	....	....	Abd
A16b	1360 R	....	0–70	70–150	150–1360	1019–1299	Sc	149	48	20,000	42	1,750	142	470	Obs
A17	2460 R	....	0–365	365–495	495–2460	{ 598–818 1340–1610	Sc	230	48	20,000	23·5	12,800	114	360	Obs
A18	926 P	....	0–478	478–620	620–926	853–895	S	42	....	....	....	....	....	750	Incomplete
A19	1930 R	....	0–571	571–700	700–1930	710–1051	Sc	90	....	....	....	....	....	820	Obs
A20	1000 P	....	0–551	551–686	686–1000	620–640	S	20	....	....	....	....	180	900	Obs
A21	1000 P	....	0–613	613–732	732–1000	934–952	S	18	48	10,700	164	....	63	540	Obs
A23	1200 R	...	0–203	203–330	330–1200	310–960	Sc	240	....	....	....	....	....	....	Incomplete
A24	1200 R	....	0–110	110–220	220–1200	300–480	Sc	130	....	....	....	....	Abt. 160	....	Obs
WL1	1810 R	....	0–343	343–435	435–1810	....	....	....	....	....	....	....	....	....	Abd
WL2	2090 R	....	0–310	310–440	440–2090	470–540	....	....	....	....	....	....	168	640	Obs
WL3	1980 R	....	....	....	0–1980	495–525	S	30	....	....	....	....	317	560	Obs
WL4	1883 R	....	....	....	0–1883	427–581	Sc	70	....	....	....	....	375	480	Obs

* P = percussion rig; R = rotary rig.

Water quality

The waters pumped from all but three of the bores had salinities less than 1,000 ppm and were therefore suitable for domestic use. The thickness of fresh groundwater is controlled by the disposition of permeable aquifers, for those of low permeability tend to contain salty water. The deep low-permeability aquifers in the western part of the area are saline, whereas in the central part of the area the deep aquifers are more permeable and contain fresh water. In the eastern part the zone of fresh water decreases (Bore A19), and at Bore WL1 the groundwater is all saline. This is the result of recharge with salty water from the east.

Groundwater movement

Contours of the potentiometric surface (Plate 1) were constructed from water levels measured on November 30, 1968. The contours indicate that the groundwater moves southeastward from the fresh-water recharge areas in the northwest, to within four to six miles of the Darling Fault. The groundwater is then deflected to the southwest, along a narrow zone through Agaton Spring, by water entering the aquifers close to the Darling Fault.

The open spacing of the potentiometric contours in the north confirms that the aquifers are more permeable in that area.

DEVELOPMENT

The northern part of the area is most suitable for development; because it is near the fresh-water intake area, the aquifers have high permeability, and salinities are low. Production bores would best be drilled within the area bounded by Bores A16, A17, A18, and A24. They could most likely produce at 40,000 to 50,000 gallons per hour each, in which case 4 to 6 bores would be needed to obtain 5 million gallons per day. These supplies could be produced from less than 1,500 feet below ground surface, and possibly less than 1,000 feet.

Whether the aquifers can yield water at this rate over a long period of time has not yet been determined. Calculation of storage coefficient awaits the results of a controlled pumping test planned for site A23, and the modes of recharge of both fresh and salt water require evaluation.

HYDROGEOLOGICAL RECONNAISSANCE OF CALCRETE AREAS IN THE EAST MURCHISON AND MT. MARGARET GOLDFIELDS

by C. C. Sanders

ABSTRACT

Calcrete valley fills of the East Murchison yield in places large supplies of potable or near potable groundwater. At Wiluna 1,000,000 gallons per day were extracted for 13 years without noticeable lowering of the water table.

A survey to locate similar calcrete deposits elsewhere in the East Murchison and Mt. Margaret Goldfields has been undertaken with little success. However, some alluviated valleys may yield sufficient groundwater for future town and industrial use. Several areas are suggested for further hydrological study.

INTRODUCTION

Calcrete is defined as a deposit of surface limestone and opaline silica generally associated with fluviatile sediments both in broad fossil valleys and in existing main drainage systems.

The calcrete deposits of the East Murchison district are very extensive and in places are known to yield large supplies of potable or near potable groundwater. The rapid expansion of mining activities in the Eastern Goldfields has caused an increased draw on the Goldfields Water Supply Scheme and these calcrete areas have been suggested as possible sources of additional water.

An investigation was made during September and October, 1968, in the hope of locating extensive calcrete formations close to projected mineral developments. The area surveyed extended over nine 1: 250,000 topographical sheets as shown on Plate 2. The area between Leonora and Kalgoorlie had previously been mapped but no calcrete deposits were recognized.

Calcretes in the East Murchison have been described by Mabbutt and others (1963), and major occurrences at Wiluna and Lorna Glen have been studied by Ellis (1953), de la Hunty (1959), Chapman (1962), Morgan (1966) and Sofoulis (1963). Ellis (1953) reported that consumption of water at Wiluna during the peak of gold mining operations was at least 1,000,000 gallons per day of potable or slightly brackish groundwater, obtained from 34 shallow wells. There was no apparent drop in the water table over 13 years at this extraction rate. The highest reported test yield from any one well was 115,000 gallons per day for seven days, the water rest level remaining steady during the test. Ellis estimated the catchment area for the Wiluna aquifer at 547 square miles. Chapman (1962) altered this to 150 square miles giving an annual recharge of the aquifer of at least 2,350 acre feet with an annual safe yield of 1,350 acre feet, equivalent to 1,000,000 gallons per day.

Brookfield *in* Mabbutt and others (1963) reporting the results of a 1958 census of all bores and wells in the Meekatharra—Wiluna—Lake Carnegie area, found that groundwater from calcrete deposits was generally of good quality and excellent for stock purposes and restricted irrigation. Water of higher salinity is often associated with formations of low effective porosity, the lower parts of valleys, and near salt lakes. The reported yields from bores and wells are not considered reliable as supplies are usually governed by equipment used and yields reflect demand rather than potential.

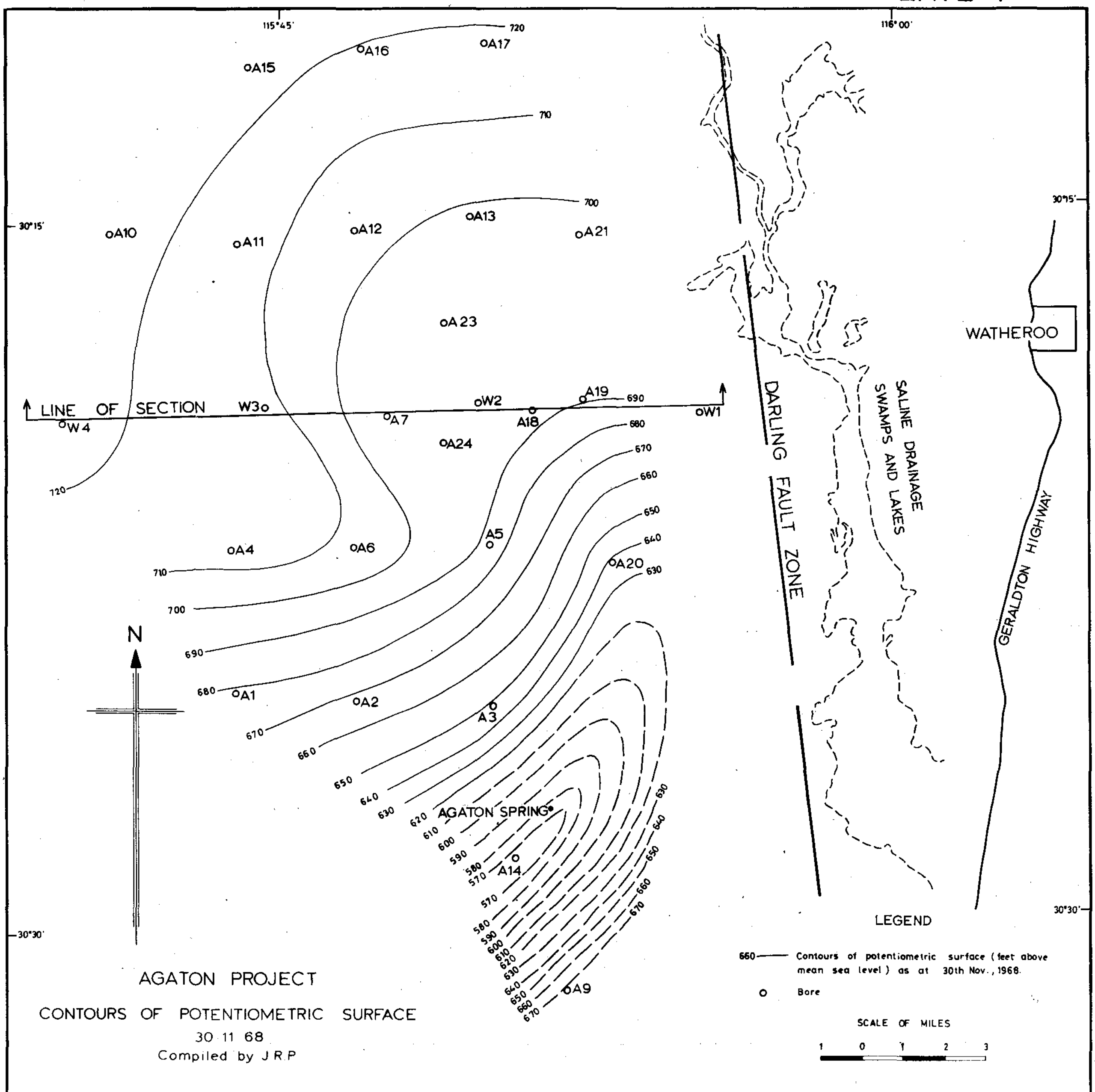
The hydrogeology of the area between Sandstone and Leonora was summarized by Morgan (1966). He showed that calcrete deposits are not common in this area and where present they occupy the slower drained main valleys or the lower parts of main tributaries, and are frequently close to salt lakes. The groundwater quality is generally poor, with a high nitrate concentration and a high hardness factor.

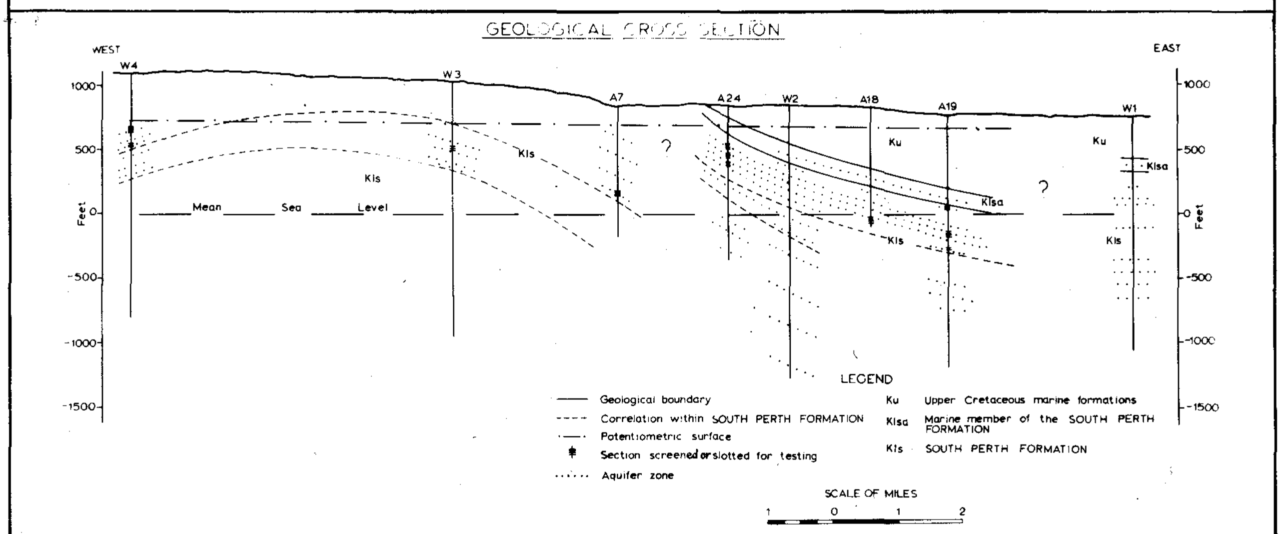
GENERAL GEOLOGY

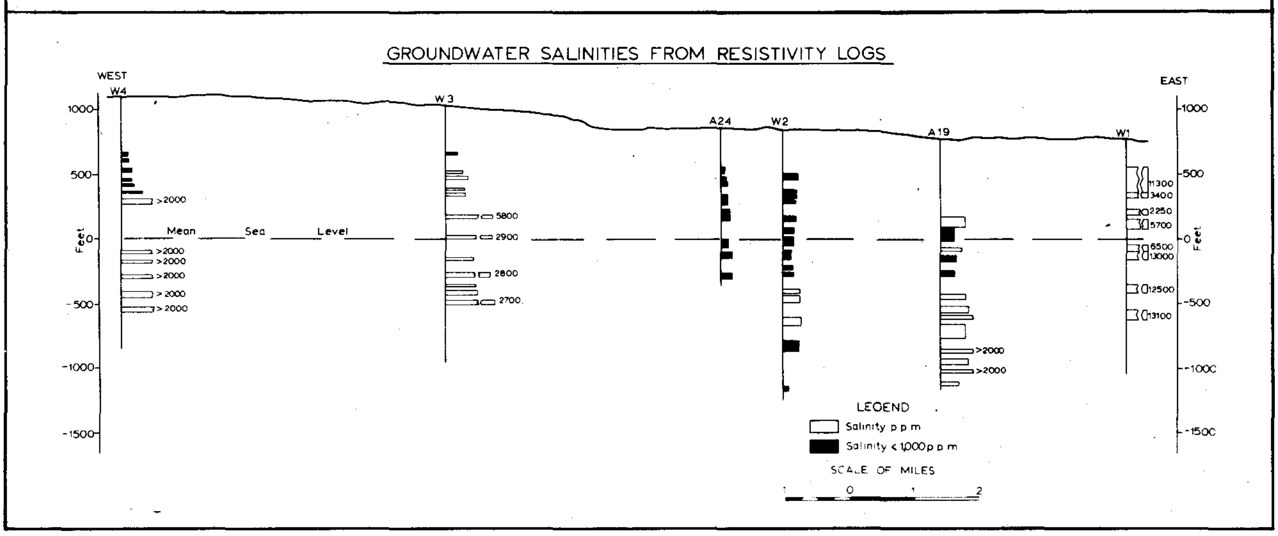
The geology of the East Murchison—Mt. Margaret Goldfields has been documented by many authors but the rocks are still poorly known and little mapped. The present intense mineral search should augment the geological information of this region.

The region falls within the Salinaland physiographic division of Jutson (1950) characterized by internal drainage terminating in salt lakes. The division forms part of the Precambrian plateau of Western Australia, underlain by Archaean granite and gneiss with belts of altered sediments and volcanic rocks and remnants of Proterozoic sediments. Capping these rocks are Tertiary and Quaternary developments of laterite and alluviated valleys. The fluviatile deposits occupy about 30 per cent. of the land surface as tributary alluvial plains and alluvial fans, calcrete valley fills and down-valley salt pans. Most of the drainage is by sheet flooding which produces smooth surfaces with minor drainage runnels, except at the watersheds where channelling is severe.

PLATE 1







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Calcrete valley fills

The main valleys and some fossil drainage channels in the Meekatharra—Lake Carnegie area are in places filled with 50 feet or more of fluviatile sediments ranging in grade from fine silt and clay through sand to coarse gravel. These are overlain in places by rubbly calcrete up to 30 feet thick with occasional bands of cellular opaline silica. Wide valley-tracts of calcrete are often continuous for many miles with low ridges parallel to the main drainage channels. Smaller developments appear as discontinuous valley trains separated by alluvium, and as isolated patches in restricted basins.

South of Wiluna calcrete is restricted to the main fossil drainages and around the larger lakes, for example, Lake Miranda at Sir Samuel. It often appears as a dissected remnant of a once much larger deposit. In the Youanmi—Leonora—Laverton area calcrete is uncommon and is found only in scattered relict patches fringing the salt lakes which now occupy the courses of the major ancient drainages.

In most areas calcrete is partly masked by the subsequent development of brown calcareous earths and in places obscured by alluvial wash. A fossil drainage system about eight miles north of Meekatharra provides an excellent example of this. There is no apparent surface indication of calcrete, although indications of it may be discerned from aerial photographs, but recent boreholes have penetrated about 35 feet of water-saturated calcareous rock. The full extent of any calcrete formation can only be found by drilling.

Calcrete probably formed as a primary chemical precipitate from solution in ground and surface waters. Sofoulis (1963) suggested that calcrete formations at different elevations along the same drainage system were deposited from "ponded" sections of the drainage after the cessation of a past period of high rainfall. The high calcium ion concentration in the waters may have been due to slow movement over calcium-rich basic igneous and metamorphic rocks.

HYDROLOGY

All main drainage tracts and calcrete areas were identified on air-photographs, prior to field inspection and sampling waters from bores and wells in their vicinity. Calcretes are extensive in the area between Meekatharra and Lake Carnegie but their occurrence and importance as aquifers diminishes towards the south. On the other hand, alluvium-filled valleys are common throughout the region and some of these appear to have good prospects of yielding fairly substantial supplies.

The occurrence and present utilisation of calcrete and alluvial valley fills are indicated in Tables 1 and 2, and positions and water salinities are shown on Plate 2. Some areas worthy of further groundwater investigations are listed below:

Glengarry 1 : 250,000 Sheet

1. The *Karalundi Mission,* 36 miles north of Meekatharra, is sited on a broad calcrete drainage system. Four wells deliver domestic and irrigation water; one well yields 15,000 gallons per hour.

2. *Hillview and Murchison Downs Stations* are traversed by a large calcrete deposit which is fed from nearby uplands and wide tributary plains. Brookfield *in* Mabbutt and others (1963) calculated the catchment area at about 590 square miles with a potential annual recharge of 8,000 acre feet.

TABLE 1. OCCURRENCE AND PRESENT UTILISATION OF CALCRETED VALLEY FILLS

1 : 250,000 Sheet	Calcrete occurrence town, station, mission	Water quality parts per million TDS	Present use	Number of bores or wells in calcrete (approximate)	Maximum reported yield in gallons per hour (gph) or gallons per day (gpd)
Glengarry	Karalundi Mission	Potable	Domestic and irrigation	4	1 well, 15,000 gph
	Meekatharra Town Bores	Potable	Exploratory	3	3 bores, 4,800 gph
	Sherwood Station	Brackish	Stock	3	*2 wells, 3,000 gpd
	Polelle Station	Brackish	Stock	5	*1 well, 5,000 gpd
	Hillview Station	1000–3000 ppm	Stock	5	*2 wells, 20,000 gpd
	Killara Station	2000–3000 ppm	Stock	3	*3 wells, 4,000 gpd
	Munarra Station	Brackish	Stock	6	*1 well, 15,000 gpd
	Diamond Well Station	Brackish	Stock	2	*1 well, 10,000 gpd
	Murchison Down Station	1000–3000 ppm	Stock	3	*1 well, 5,000 gpd
	Paroo Station	700–1750 ppm	Stock	8	*8 wells, 4,000 gpd
	Yandill Station	1750–14,000 ppm	Stock	6	1 well, 120,000 gpd
Wiluna	Cunyu Station	350–950 ppm	Domestic and stock	2	*1 well, 20,000 gpd
	Wiluna Town Bores	740–860 ppm	Domestic	6	1 well, 115,000 gpd
	Millbillillie Station	900–4000 ppm	Stock	8	*1 well, 8,640 gpd
	Lake Way Station	5000 ppm	Stock	1	*1 well, 10,800 gpd
	Albion Down Station	2142 ppm	Stock	1	....
	Lake Violet Station	750–3000 ppm	Stock	5	*3 bores, 3,000 gpd
	Millrose Station	Brackish	Stock	3	*2 wells, 5,000 gpd
	Lorna Glen Station	Saline	Stock	3	1 well, 20,000 gpd
Kingston	Lorna Glen Station	600 ppm	Domestic and irrigation	4	*1 well, 280,000 to 480,000 gpd
	Windidda Station	Saline	Stock	3	*1 well, 9,000 gpd
	Bonython Creek Station	....	Stock	2	....
Sandstone	Hillview Station	1500–5500 ppm	Stock	7	*7 bores, 4,000 gpd
	Cogla Downs Station	2000–5900 ppm	Stock	4	*1 bore, 5,000 gpd
	Lake Mason Station	2000–6000 ppm	Stock	5	*5 bores, 4,000 gpd
	Yeelirrie Station	2200–11,000 ppm	Stock	4	*3 bores, 5,000 gpd
Sir Samuel	Yeelirrie Station	1750–9000 ppm	Stock	5	*5 wells and bores, 5,000 gpd
	Depot Springs Station	650–10,000 ppm	Stock	3	....
	Yakabindie Station	2000–6000 ppm	Stock	10	*2 bores, 4,000 gph
	Leinster Downs Station	3000–4000 ppm	Stock	2	....
	Weebo Station	440–5200 ppm	Stock and irrigation	3	*1 well, 5,000 gph
	Yandal Station	3000 ppm	Stock	2	....
	Barwidgee Station	650–5900 ppm	Stock	3	*1 well, 14,000 gpd
Duketon	Banjawarn Station	350–5000 ppm	Stock and minor irrigation	7	*1 bore, 50,000 gpd
Youanmi	Yuinmery Station	1000–7000 ppm	Stock	5	*1 well, 24,000 gpd
	Dandaraga Station	1750–5000 ppm	Stock	5	....
	Cashmere Downs Station	Saline	Stock	2	....
Leonora	Pinnacles Station	2500–8000 ppm	Stock	5	....
	Sturt Meadows Station	500–1200 ppm	Stock	5	*5 bores, 5,000 gpd
	Clover Downs Station	3000 ppm	Stock	1	....
Laverton	Nambi Station	8000 ppm	Stock	2	....
	Erlistoun Station	2500–10,000 ppm	Stock	3	*1 bore, 4,000 gpd
	Korong Station	2400 ppm	Stock	1	....

* Indicates pump capacity rather than potential yield of well or bore.

TABLE 2. OCCURRENCE AND PRESENT UTILISATION OF ALLUVIAL DRAINAGES

1 : 250,000 Sheet	Alluvial occurrences town, station, mission	Water quality parts per million TDS	Present use	Number of bores or wells in alluvium (approximate)	Maximum reported yield gallons per hour (gph) or gallons per day (gpd)
Glengarry	Meekatharra Town Bores	740–1280 ppm	Town supply	9	2 wells, 1,100 gph
	Sherwood Station	Brackish	Stock	19	*19 wells and bores, 1,000 gpd
	Polelle Station	800–3000 ppm	Stock	14	*10 wells and bores, 8,000 gpd
	Hillview Station	800–3000 ppm	Stock	7	*1well, 4000 gpd
	Killara Station	800–2500 ppm	Stock	3	*3 wells, 4,000 gpd
	Munarra Station	1250–3000 ppm	Stock	15	*4 wells, 10,000 gpd
	Diamond Well Station	Brackish	Stock	2	*1 well, 20,000 gpd
	Mooloogool Station	? Brackish	Stock	10	*1 well, 28,000 gpd
	Murchison Down Station	1000–Brackish	Stock	10	*2 wells, 5,000 gpd
	Paroo Station	710–Brackish	Stock	12	*9 wells, 2,000–4,000 gpd
	Yandil Station	1350–Brackish	Stock	10	1 well, 100,800 gpd
	Albion Downs Station	1000–Brackish	Stock	8	*2 bores, 7,000 gpd
Wiluna	Wiluna Agriculture Research Station	1360 ppm	Irrigation	2	1 bore, 11,000 gph 1 bore, 7,000 gph
	Millbillillie Station	1750–3000 ppm	Irrigation	3	1 bore, 3,750 gph
	Millbillillie Station	1500–2750 ppm	Stock	11	*7 wells, 2,000 gpd
	Lake Way Station	1000–Brackish	Stock	16	*1 well, 20,000 gpd 1 well, 12,000 gpd
	Lake Violet Station	1500 ppm	Irrigation	3	2 bores, 5,000 gph
	Lake Violet Station	1500–3000 ppm	Stock	12	*1 well, 2,000 gph
	Millrose Station	1000–Brackish	Stock	6	*6 wells, 2,000 gpd
	Jundee Station	1000–3000 ppm	Irrigation and stock	5	1 well, 216,000 gpd 1 well, 116,000 gpd
	Barwidgee Station	750–1025 ppm	Stock	4	....
	Lorna Glen Station	620–2000 ppm	Stock	4	*2 bores, 36,000 gpd
Kingston	Lorna Glen	580–2300 ppm	Stock	3	1 well, 100,000 gpd
	Windidda Station	Brackish	Stock	2	....
Sandstone	Hillview Station	650–1500 ppm	Stock	3	....
	Yarrabubba Station	Brackish	Stock	7	....
	Cogla Down Station	2000–5000 ppm	Stock and minor irrigation	5	*1 bore, 15,000 gpd
	Lake Mason Station	150–5250 ppm	Domestic and stock	4	*1 bore, 3,000 gph
	Yeelirrie Station	750–1800 ppm	Stock	2	*2 bores, 5,000 gpd
Sir Samuel	Yeelirrie Station	400–5800 ppm	Minor irrigation and Stock	4	*1 well, 15,000 gpd
	Albion Downs Station	900–3000 ppm	Irrigation and stock	12	6 bores, 3,000–5,000 gph
	Depot Springs Station	900–1500 ppm	Stock	4	....
	Yakabindie Station	790–5200 ppm	Stock	9	*2 wells, 150 gph
	Yandal Station	1250 ppm	Stock	2	....
	Weebo Station	666 ppm	Domestic	1	....
	Barwidgee Station	650–4000 ppm	Minor irrigation and stock	7	....
Duketon	Banjawarn Station	800–2000 ppm	Stock	4	....
Youanmi	Yuinmery Station	295–5800 ppm	Stock	8	*1 well, 24,000 gpd
	Dandaraga Station	1150–2500 ppm	Stock	14	....
	Cashmere Downs Station	Brackish	Stock	2	....
Leonora	Pinnacles Station	500–5990 ppm	Stock	18	....
	Pinnacles Station	1400 ppm	Irrigation (abd)	7	7 bores, 40,000 gpd
	Sturt Meadows Station	620–2900 ppm	Minor irrigation and stock	12	*1 well, 7,000 gph
	Clover Downs Station	2000–4000 ppm	Stock	4	....
	Leonora Town Bores	1300 ppm	Domestic	4	3 wells, 2,000 gph 1 well, 1,000 gph
Laverton	Nambi Station	790–1800 ppm	Minor irrigation and stock	4	....
	Erlistoun Station	2500–5500 ppm	Stock	9	*3 wells, 5,000 gpd
	Korong Station	2500–5500 ppm	Stock	5	*3 wells, 5,000 gpd

* Indicates pump capacity rather than potential yield of well or bore.

3. *On Paroo and Yandil Stations* extensive calcrete and alluvial aquifers give groundwater containing 700 to 1,750 ppm, total salts; one well has been tested at 120,000 gallons per day, and another at 100,800 gpd. This system is probably the largest in the East Murchison, far exceeding the Wiluna aquifer in dimension and catchment area. Brookfield estimates the catchment area to cover 1,270 square miles with a potential annual recharge of 25,500 acre feet.

Wiluna 1 : 250,000 Sheet

1. At *Cunyu Station,* 40 miles north of Wiluna, potable water is obtained from calcrete at the rate of 20,000 gpd, but no adequate pump-test has been carried out. The catchment area is at least 240 square miles with an estimated annual recharge of 4,500 acre feet (Brookfield in Mabbett and others, 1963).

2. The *Wiluna* aquifer, six miles east of the town, is reported to have yielded 1,000,000 gpd without noticeable lowering of the water table. The catchment area is about 150 square miles and annual recharge has been calculated by Chapman (1962) as 2,350 acre feet.

3. At *Lorna Glen Station,* 100 miles northeast of Wiluna, potable water is pumped from calcrete at up to 480,000 gpd. Chapman reported a catchment area of about 50 square miles and an annual recharge of 350 acre feet.

Sir Samuel 1 : 250,000 Sheet

1. On *Albion Downs Station* a localized alluvial aquifer is used for irrigation and domestic supply. Six bores are reported to yield between 3,000 and 5,000 gallons per hour.

2. On *Yakabindie and Leinster Downs Stations* three fossil calcrete drainages terminate in Lake Miranda. Salinities are rather high (2,000 to 6,000 ppm TDS) but the amount of available water is probably quite large. No adequate pump-testing has been done.

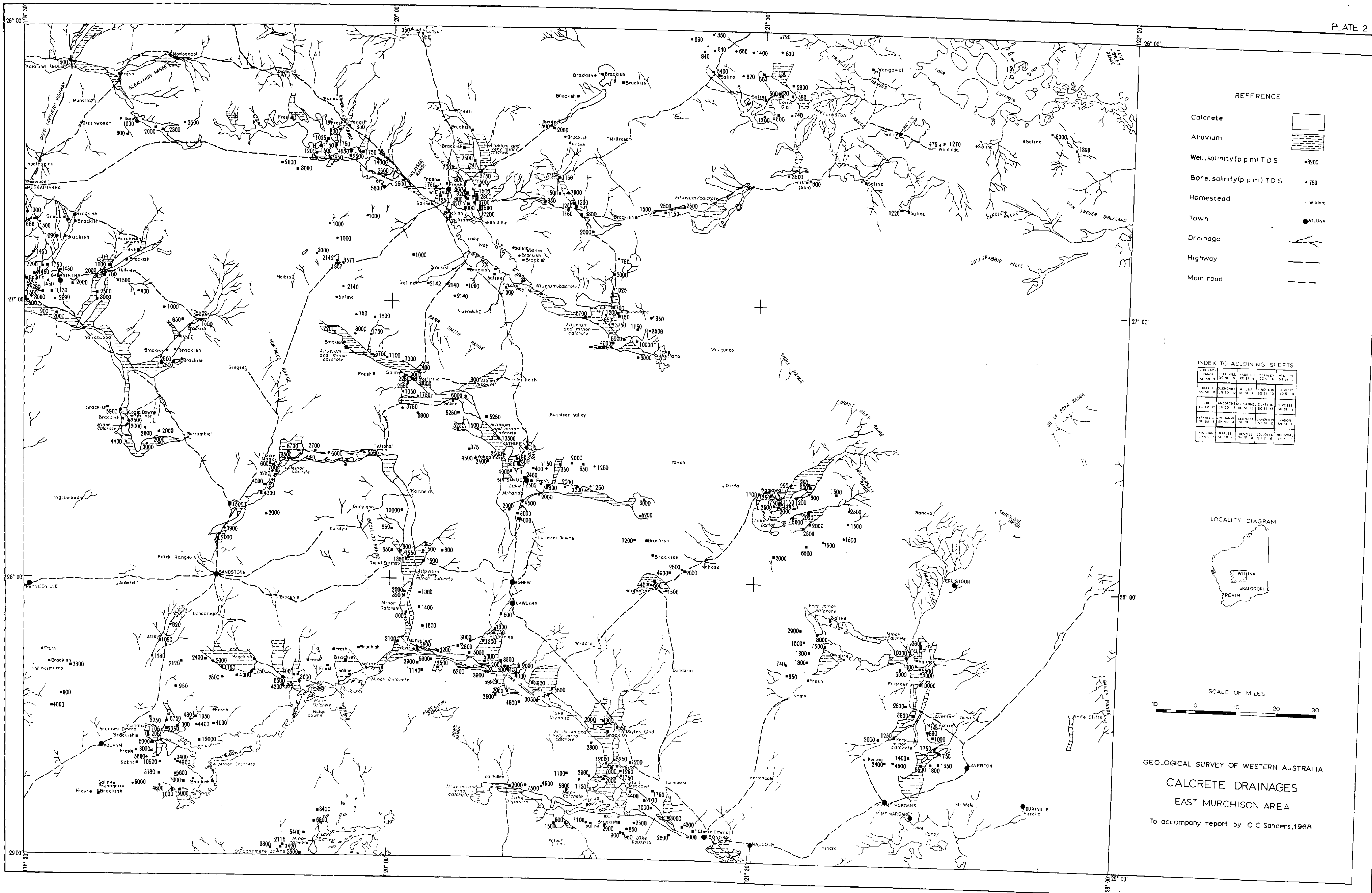
Duketon 1 : 250,000 Sheet

1. *Banjawarn Station* on Lake Darlot is sited over calcrete and alluvial aquifers associated with the Erlistoun and Vickers Creek drainage system. Salinities range from 350 to 5,000 ppm TDS, and one bore yields at least 50,000 gallons per day.

Leonora 1 : 250,000 Sheet

1. Many suggesions have been made over the last 60 years to dam or intensively bore the Wilson Creek drainage system on *Sturt Meadows Station,* some 40 miles northwest of Leonora. The system is an alluvial area of about 50 square miles fed from numerous creeks draining nearby uplands. From about 1920 to 1940 potable water at a 'great supply' was obtained from Doyles Well on Wilson Creek for a now abandoned hotel and swimming pool.

PLATE 2



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2. *Leonora Townsite* and the *Sons of Gwalia Goldmine* were supplied with groundwaer containing 1,000 to 2,000 ppm TDS from bores sunk in alluvial areas around the town. The present Leonora supply is near Four Mile Creek from four wells, 60 to 70 feet deep, each yielding up to 2,000 gph. All bores can be pumped out. Additional supplies could be obtained by drilling farther downstream.

3. An unusual underground water occurrence not related to calcrete and which might be exploited has been reported from the *Emu Goldmine* at Agnew. Slightly brackish pressure water was struck at the 960 feet level, the water rose about 700 feet, and was pumped from the mine at the rate of 1,000,000 gpd for three months before the water was controlled.

CONCLUSIONS AND RECOMMENDATIONS

Calcrete valley fills are not persistent throughout the East Murchison—Mt. Margaret Goldfields, although they form important but mainly untested aquifers in the Meekatharra—Lake Carnegie area, their importance diminishing toward the south. Some alluvial drainage tracts may provide usable groundwater in the southern region. Further hydrological studies, following by drilling, could be under taken with advantage in such areas as Karalundi Mission, Hillview and Murchison Downs Stations, Paroo and Yandil Stations, Cunyu Station, Lorna Glen Station, and at Wiluna in the East Murchison Goldfield; Albion Downs Station, Yakabindie Station and Banjawarn Station in the Sir Samuel —Lake Darlot area; and at Doyles Well on Sturt Meadows Station, Leonora. The Emu Goldmine at Agnew and alluviated areas near Leonora could give additional supplies.

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MILLSTREAM HYDROGEOLOGICAL INVESTIGATION

by W. A. Davidson

ABSTRACT

Exploratory drilling of calcretes in the vicinity of Millstream, on the Fortescue River, has shown that they are situated in a trough and have an average saturated thickness of 35 feet. The calcrete aquifer covers an area of at least 80 square miles and has limited interconnection with the Fortescue River.

Approximately 8 million gallons per day of potable water, suitable for town supply, can be pumped from the calcrete without reducing the volume of water in storage, if normal recharge takes place. It is estimated that about 80 x 10^9 gallons are in storage.

INTRODUCTION

Millstream Station homestead is on the Pyramid 1 : 250,000 Sheet, about 85 miles southeast of Dampier.

Following a geological reconnaissance during February, 1968, the Geological Survey, at the request of the Public Works Department, investigated the possibility of obtaining from the Millstream calcretes 10 million gallons per day of potable water for industrial and domestic use. This is required at Dampier by iron ore companies.

The calcretes are situated in an arcuate strip of country convex to the north, approximately 35 miles long and 5 miles wide, the centre being about 2 miles south of Millstream homestead.

INVESTIGATIONS

Gravity survey

A gravity survey was made to help delineate the bedrock and as an aid to selecting bore sites. Results are at Appendix I.

Drilling programme

Twenty-five bores were drilled on eight cross-sections (Plate 4), and accurately levelled. Depths ranged from 60 feet to 195 feet, total footage drilled being 3,506 feet. Three percussion cable tool rigs and one rotary percussion rig were used. Fourteen bores were pump-tested for 8-hour periods.

Drilling samples were collected at 10 feet intervals and at changes of strata. However, in cavernous calcrete, samples were often unobtainable by the rotary percussion rig.

The drilling results have been summarized in Table 1.

GEOLOGY

The Millstream area has been regionally mapped by M. Kriewaldt and G. R. Ryan (1965) on the Pyramid 1 : 250,000 Sheet and by I. R. Williams (1968) on the Yarraloola 1 : 250,000 Sheet.

Regional setting (Plate 3)

Surrounding and underlying the calcrete is a Proterozoic sequence with a regional southerly dip of less than 3 degrees. The succession in the Millstream area is thus:

Hamersley Group	Wittenoom Dolomite (Phd) Marra Mamba Iron Formation (Phm)	
——conformity——		
Fortescue Group ..	Roy Hill Shale Member (Pfjr) Warrie Member (Pfjw)	Part of the Jeerinah Formation

Bedrock

Wittenoom Dolomite. At the base of the Hamersley Scarp, and to the south of the calcrete valley fill, grey to light brown calcitic dolomite may be seen in outcrop. It is thin to thick bedded and is often compact and well indurated.

TABLE 1. MILLSTREAM DRILLING RESULTS

Bore name	Total depth	Estimated valley fill calcrete and clay	Thickness saturated aquifer	Bedrock or basement	Reduced static water level: Feet	Reduced static water level: Date	Pump—Test: g.p.h.	Pump—Test: Hrs.	Pump—Test: Draw-down	Salinity pumped sample	Total casing	Remarks
	ft	ft	ft						ins	ppm	ft ins	
Line 1—A	134	45	38	Pfjr	963·925	19/10/68	14,900	8	2	670	58 10¾	Prospective calcrete
B	91½	58	36	Phm	964·405	3/10/68	14,900	8	Nil	720	43 3	Prospective calcrete
C	136	93	57	Weathered Phm	964·527	19/10/68	14,900	7½	123	600	60 4½	Prospective calcrete
D	148½	102	34	Weathered Phm	964·513	19/10/68	14,900	7	Nil	570	91 2½	Prospective calcrete
Line 2—A	¾	Unknown		Unknown	Dry	30/9/68	....	....	....	590	....	Abandoned
B	181	94	24	Pfjr	964·452	30/9/68	15,000	8	Nil	500	94 10¾	Prospective calcrete
C	195	150	74	Weathered Pfjr	964·418	30/9/68	....	....	....	630	138 4½	Prospective calcrete
D	148	98	21	Weathered Pfjr	964·478	1/10/68	25,600	8	13	470	101 3½	Prospective calcrete
Line 3—A	120	80	55	Weathered Pfjr	964·445	15/10/68	25,600	5	Nil	1150	53 8	Prospective calcrete
Line 4—A	187	105	31	Weathered Pfjr	964·309	1/10/68	25,600	8	10½	520	95 0½	Prospective calcrete
B	150	100	23	Phm	964·399	1/10/68	....	....	....	560	99 1	Prospective calcrete
C	175	130	55	Phd	964·469	1/10/68	....	....	....	570	139 6¾	Prospective calcrete
D	154	100	23	Weathered Phm	965·416	1/10/68	6,600	8	112½	720	94 7¾	Unprospective calcrete
Line 5—A	152	110	73	Weathered Phm or Pfjr	964·840	16/9/68	....	....	....	1040	115 6	Prospective calcrete
B	150	135	70	Weathered Phm	964·770	12/9/68	25,600	4	Nil	940	93 10	Prospective calcrete
C	120	90	39	Possibly weathered Phd	964·892	16/9/68	....	....	....	530	81 7	Prospective calcrete
Line 6—A	100	45	....	Pfjr	974·446	2/10/68	....	....	....	500	81 6¾	Unprospective Phm
B	116	88	16	Weathered Phm	964·356	2/10/68	1,500	1	160	740	86 4¾	Unprospective calcrete
Line 7—A	125	90	42	Weathered Phm	964·101	30/9/68	....	....	....	540	97 11½	Prospective calcrete
B	156	100	31	Weathered Pfjr	964·434	3/10/68	25,600	8	30½	580	102 4½	Prospective calcrete
C	175	165	93	Weathered Pfjr	964·420	6/9/68	....	....	....	480	122 0	Prospective calcrete
D	148	105	29	Weathered Pfjr	964·411	3/10/68	25,600	7¾	26	510	99 3¾	Prospective calcrete
Line 8—A	60	40	Nil	Phm	Dry	6/9/68	....	....	....	Dry	....	Dry
B	145	90	27	Weathered Phm	964·356	6/9/68	....	....	....	1010	97 4	Prospective calcrete
C	162	130	53	Weathered Phm and Pfjr	964·621	6/9/68	23,700	8	31½	570	103 1	Prospective calcrete

Pilot holes drilled partly by rotary percussion rig and later reamed and deepened by cable tool plant.

Samples obtained during the drilling of Line 4-C bore indicate that the dolomite is well bedded and in general not very permeable, though it may be cavernous in places.

Dolomitic shale and thin chert bands are present at the top of the formation.

Marra Mamba Iron Formation. In the Millstream area the Marra Mamba Iron Formation has been deeply dissected and eroded to form thin caps, approximately 20 to 40 feet thick, overlying the Roy Hill Shale. The formation is characterized by a dominance of blue-black chert and subordinate jaspilite, often with pinch and swell structures.

Roy Hill Shale Member. This member lies at the top of the Jeerinah Formation and is a leached white shale, silicified in places, up to 120 feet thick. Drilling has shown that the shale is capped by an ironstone layer 5 to 10 feet thick, which sometimes contains pyrite nodules with hematite pseudomorphs after pyrite.

In some of the bores, fresh bedrock was encountered during drilling, but most bores terminated in weathered bedrock.

Calcrete and associated sediments

Although most of the calcrete aquifer lies south of the Fortescue River, there is a substantial outcrop of calcrete northeast of Deep Reach Pool. However, the base of the calcrete in this direction is thought to be mainly above the groundwater table and hence it is not water bearing. The base of the calcretes which straddle the watershed between the Fortescue and the Robe catchment is above the water table, except for a narrow zone confined to the westward extension of the main sedimentary trough.

The sediments in the trough follow the general sequence:

- Calcrete and silcrete often covered with a thin veneer of clay-loam gilgai.
- Clays (generally with some silica).
- Weathered bedrock and variegated clay.
- Bedrock (Wittenoom Dolomite, Marra Mamba Iron Formation, or Roy Hill Shale).

The highly cavernous and permeable calcrete, as shown in outcrop, generally overlaps the underlying clays which are often calcrete and/or silcrete impregnated. Impure calcrete then rests directly on weathered bedrock, the contact being poorly defined by the presence of weathering products such as grit and variegated clays.

Towards the western margins and in particular the margin southwest of Jones Creek Well and the breakaway near Palm Creek Spring, the calcrete often passes downward into a conglomerate in a lime matrix, which would tend to indicate that at least part of the calcrete valley fill contains alluvial material. Between 115 and 135 feet in Bore 5-B coarse-grained, moderately sorted, calcareous and siliceous fragments were encountered during drilling, suggesting an ancient river channel.

The base of the calcrete is very irregular and it is estimated that the reduced levels of the base extend over the range 871 to 1,004 feet. The upper surface of the calcrete, although generally fairly flat, lies at elevations between 1,040 and 970 feet. The greatest topographical relief is near the northeast and southwest margins. The total thickness of calcrete, therefore, varies considerably, the maximum being about 150 feet between Bore 2-C and Bore 7-C. The saturated thickness also varies widely, reaching a maximum of about 93 feet.

The trough

The shape and depth of the trough is a reflection of the ease of erosion of the various types of bedrock, their degree of resistance being:

Marra Mamba Iron Formation	Most resistant.
Wittenoom Dolomite.	
Roy Hill Shale	Least resistant.

The trough is therefore deepest where erosion has cut into the Roy Hill Shale.

The transition from calcerous clays to weathered bedrock to fresh bedrock prevents accurate determination of bedrock relief, but a good approximation of the form of the sedimentary trough may be made by using the base of the calcareous clay as a reference (Plate 4).

Drilling samples show that there is a general deepening of the trough towards the Hamersley Range drainage slope and particularly in the vicinity of Bore 7-C. To the southwest the centre of the trough rises gradually to at least 1,040 feet within the Robe catchment area. East of Line 5 the form of the trough is unknown. Between Line 2 and Line 7 the form of the trough is complicated by the development of a ridge as indicated on Plate 4.

The general form of the trough, therefore, supports the theory that the calcrete was deposited in an ancient channel and that there has been river piracy by the Fortescue River capturing the headwaters of the Robe River.

The present Fortescue River flows westward following the less resistant Roy Hill Shale and then cuts through a water gap breaching the more resistant Proterozoic rocks in the Gregory Gorge area to continue on the coast.

HYDROLOGY

Rainfall

Millstream Station has an annual rainfall of between 13 and 14 inches mostly from summer cyclones, although about 7½ inches of unseasonal winter rains were recorded by the Public Works Department during 1968.

Aquifers

Bedrock. The Marra Mamba Iron Formation contains small quantities of water in fractures and weathered zones, and supplies some station wells. The water in Bore 6-A comes from the same formation, but the supply is not good. The Roy Hill Shale is also not very permeable. The Wittenoom Dolomite in Bore 4-C is well below the present water table, but appears too impermeable to be a likely source of water unless it proves cavernous in places.

Calcrete. Around its margins, and in particular to the northeast and southwest, the floor of the calcrete rises above the present water table so that the saturated area of 80 square miles or so is much less than the surface extent.

The calcrete often contains bands of very hard opaline silica, but is usually very pervious and sometimes cavernous. Towards its base the permeability is much less because of a higher clay content. The average saturated thickness has been calculated at 35 feet of which possibly only 30 feet will yield much water.

Alluvium. The aquifer in the vicinity of Howlett's Well is possibly a river alluvium consisting largely of clays and having a low-to-moderate porosity, which possibly accounts for the wide variations in rest levels. In this well fluctuations in excess of 10 feet are known to occur.

Hydraulic Surface

Static water levels have been measured accurately. The water table in the saturated calcrete is substantially flat with a range of elevations between 963.93 and 965.42 feet (Plate 4). Towards the margins of the calcrete and in weathered bedrock zones the range of elevations is generally higher, from 971.22 to 974.45 feet.

Pools associated with springs from the calcrete, and in particular Deep Reach Pool in the Fortescue River, show elevations less than those found in the main body of calcrete. Deep Reach Pool had an elevation of 958.39 feet on the 15th October, 1968. This may indicate low permeability within the calcrete aquifer in its vicinity, or more likely, that the pools are fed by springs. These rise in small erosion channels cut in the bedrock which subsequently have been infilled with calcrete rubble and clay, and connect the main body of the aquifer to the pools.

During dry season conditions the water level in Deep Reach Pool falls to a level at least 5 feet below that in the calcrete and as the nearest borehole tapping the main aquifer is about 3,000 feet away a comparatively steep hydraulic gradient is established. This is much steeper than the gradient within the main mass of calcrete where it seems unlikely to exceed 1 foot in 25,000 feet. It may be assumed, therefore, that the transmissivity in the main body of the aquifer is very much higher than that near the banks of the Fortescue. This may indicate that river alluvium or weathered bedrock, or both, separate Deep Reach Pool from the calcrete aquifer.

Before recharge to the calcrete south of Deep Reach Pool could take place from the river, the water level of the pool would have to rise more than 5 feet. As this very seldom occurs, recharge to the calcrete from this source will only take place during exceptionally high floods. During normal river flow and minor flooding, recharge to the calcrete will not take place at this locality.

The hydraulic gradient of 2 feet in 300 feet between Bore 1-A and the pool at Millstream Spring in conjunction with the general form of the trough, as shown on Plate 3, indicates that the general flow of water within the calcrete is towards Millstream homestead.

TABLE 2. MILLSTREAM GROUNDWATER—GOVERNMENT CHEMICAL LABORATORIES—STANDARD ANALYSES

Source	Specific conductivity micromhos 20° C.	pH	Appearance	Colour	Odour	MINERAL MATTER—PARTS PER MILLION																			
						T.D.S. evaporation	T.D.S. conductivity	NaCl (calc. from chloride)	Total hardness (calc. as $CaCO_3$)	Total alkalinity (calc. as $CaCO_3$)	Ca	Mg	Na	K	Fe	F	HCO_3	CO_3	SO_4	Cl	NO_3	SiO_2
Line 1—A	950	7·2	Clear	Colourless	Nil	660	660	214	380	305	72	49	93	18	0·1	0·7	396	Nil	71	137	7	59
B	1040	7·4	Clear	Colourless	Nil	720	730	242	417	335	86	49	85	12	0·1	0·7	408	Nil	70	147	3	58
C	890	7·5	Clear	Colourless	Nil	600	620	207	386	271	72	50	62	9	0·1	0·8	330	Nil	80	126	1	41
D	810	7·4	Clear	Colourless	Nil	570	560	171	336	270	68	40	63	10	0·1	0·6	329	Nil	59	104	8	57
Line 2—B	760	7·4	Clear	Colourless	Nil	500	530	154	303	260	57	39	61	7	0·1	....	317	Nil	39	93	15	44
C	920	7·3	Clear	Colourless	Nil	630	640	222	392	260	76	49	63	9	0·1	....	317	Nil	86	135	1	24
D	640	7·6	Clear	Colourless	Nil	470	450	150	256	231	48	33	64	7	0·1	....	281	Nil	29	91	17	61
Line 3—A	1660	7·4	Clear	Colourless	Nil	1150	1160	542	552	325	99	74	178	22	0·1	....	396	Nil	165	329	7	60
Line 4—A	730	7·2	Clear	Colourless	Nil	520	510	198	254	195	49	32	73	5	0·1	....	238	Nil	48	120	7	51
B	900	7·4	Clear	Colourless	Nil	560	630	274	359	225	58	52	76	5	0·1	2·1	274	Nil	47	166	27	7
C	850	7·4	Clear	Colourless	Nil	570	600	180	319	260	60	41	80	8	0·1	0·8	317	Nil	79	109	9	10
D	1010	7·5	Clear	Colourless	Nil	720	710	227	364	290	75	43	99	10	0·1	....	354	Nil	87	138	22	56
Line 5—A	1440	7·9	Clear	Colourless	Nil	1040	1010	450	470	276	73	70	166	16	0·1	....	336	Nil	179	273	6	51
B	1370	7·1	Clear	Colourless	Nil	940	960	417	469	295	84	63	140	18	0·1	....	360	Nil	134	253	6	56
C	750	8·0	Clear	Colourless	Nil	530	520	178	275	215	44	40	68	8	0·1	....	262	Nil	57	108	7	50
Line 6—A	740	7·8	Clear	Colourless	Nil	500	520	199	217	170	54	20	83	5	0·1	....,	207	Nil	48	121	17	61
B	1020	7·6	Clear	Colourless	Nil	740	710	366	400	170	79	49	83	7	0·1	....	207	Nil	88	222	15	51
Line 7—A	780	7·6	Clear	Colourless	Nil	540	550	152	317	266	56	43	62	10	0·1	....	324	Nil	60	92	9	46
B	810	7·4	Clear	Colourless	Nil	580	570	185	253	276	69	44	67	10	0·1	....	336	Nil	65	112	14	54
C	640	7·5	Clear	Colourless	Nil	480	450	140	278	210	52	36	47	8	0·1	....	256	Nil	51	85	10	47
D	700	7·6	Clear	Colourless	Nil	510	490	142	295	266	59	36	63	8	0·1	....	323	Nil	45	86	11	53
Line 8—A	- - -	- -	- - -	- - - - - -	- -	- - -	- -	- - -	- -	- -D	R	Y-	- -	- -	- - -	- -	- - -	- - -	- -	- - -	- -	-
B	1400	7·8	Clear	Colourless	Nil	1010	980	553	411	189	82	50	177	8	0·1	....	232	Nil	128	336	10	51
C	860	7·7	Clear	Colourless	Nil	570	600	190	302	231	55	40	72	8	0·1	....	281	Nil	64	115	12	53
Irvine Well	1750	8·2	Clear	Colourless	Nil	1270	1220	626	614	305	101	88	185	20	0·1	....	372	Nil	186	380	9	54
Bloom Well	1770	8·2	Clear	Colourless	Nil	1290	1240	626	528	266	83	78	215	23	0·1	....	324	Nil	210	380	5	54
Chinaman Well	1010	7·7	Clear	Colourless	Nil	840	710	242	532	361	104	66	56	11	0·1	....	440	Nil	65	147	40	48
No. 3 Bore	980	7·6	Clear	Colourless	Nil	680	690	257	367	266	76	43	92	10	0·1	....	324	Nil	80	156	14	51
Pans Well	550	8·1	Clear	Colourless	Nil	430	380	109	248	225	58	25	48	4	0·1	....	274	Nil	26	66	14	55
Jones Ck. Well	1040	7·7	Clear	Colourless	Nil	700	730	313	461	295	109	46	64	13	0·1	....	360	Nil	43	190	11	51
Johnsons Well	770	8·1	Clear	Colourless	Nil	540	540	181	297	236	53	40	66	8	0·1	....	287	Nil	44	110	19	41
Pump Bore No. 14	900	7·5	Clear	Colourless	Nil	630	630	206	368	295	70	47	76	9	0·1	....	360	Nil	61	125	11	45
No. 4 Bore	1610	8·0	Clear	Colourless	Nil	1170	1130	542	545	310	96	74	187	20	0·1	....	378	Nil	189	329	6	65
Deep Reach Pool	1820	7·8	Clear	Colourless	Nil	1180	1275	610	570	290	92	83	196	20	0·1	....	353	Nil	200	368	6	59

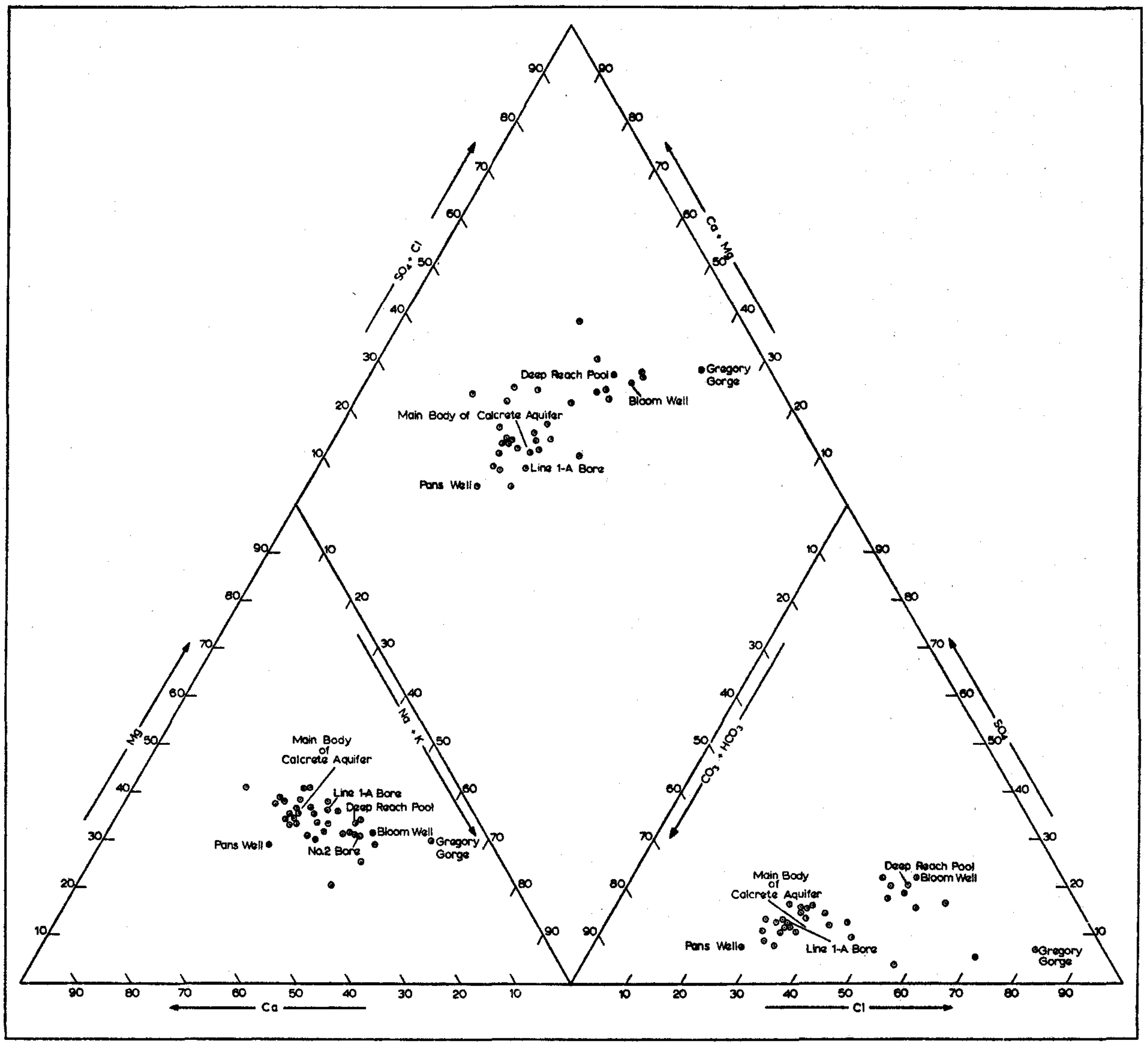


Figure 3. Hydrochemistry of Millstream groundwater.

Hydrochemistry

Standard analyses. Water sample analyses (Table 2) show that there is a high proportion of sodium and chlorine ions in water associated with weathered bedrock. A high concentration of these ions also occurs in the various pools and in particular the pool at the Gregory's Gorge. In the central part of the calcrete aquifer where concentration of sodium and chlorine ions is lower, there is a tendency for the water to be relatively high in bicarbonate and hence hard.

A trilinear diagram (Figure 3) illustrates the variations in chemical composition.

Salinity pattern (Total Dissolved Solids). From a study of the isohalsines drawn on Plate 4 the following deductions have been made:

(1) Groundwater in the large central area of the calcrete aquifer has a salinity range of approximately 450 to 750 ppm.

(2) Towards the margins of the calcrete and into the surrounding Proterozoic Formations the salinity range is higher, the range being 750 to 1,380 ppm. A sample from Gregory's Gorge had a salinity count of 2,180 ppm, undoubtedly the result of evaporative concentration.

(3) The immediate runoff from the bare drainage slope of the Hamersley Range has produced an area of low salinity shown on the southern central portion of the plan.

(4) To the southwest and in the vicinity of Pans Well the groundwater has a very low salinity of about 430 ppm suggesting direct intake from rainfall.

(5) The comparatively high salinity of groundwater associated with Proterozoic rocks is probably the result of low permeability of these strata, and that of the river pools is almost certainly the result of evaporation.

(6) At the eastern limits of the area there is a low salinity tongue extending eastward, which approximately follows the axis of the calcrete trough shown on Plate 3.

(7) The low salinity near Howlett Well results from local intake of rainwater and posibly some flow in Howlett Creek.

(8) The groundwater in station bores 1 and 2 show a fluctuation in salinity due to the winter rains.

	Before Rains	After Rains
Bore 1	1,380	430
Bore 2	1,200	230

Pump-Tests

Of the 25 exploratory boreholes, 14 were pump-tested for about 8 hours. The results (Table 1) indicate that low permeability or a low storage coefficient may be the cause of low pumping rates and comparatively large drawdowns in the calcrete aquifers in Bores 1C, 4D and 6B.

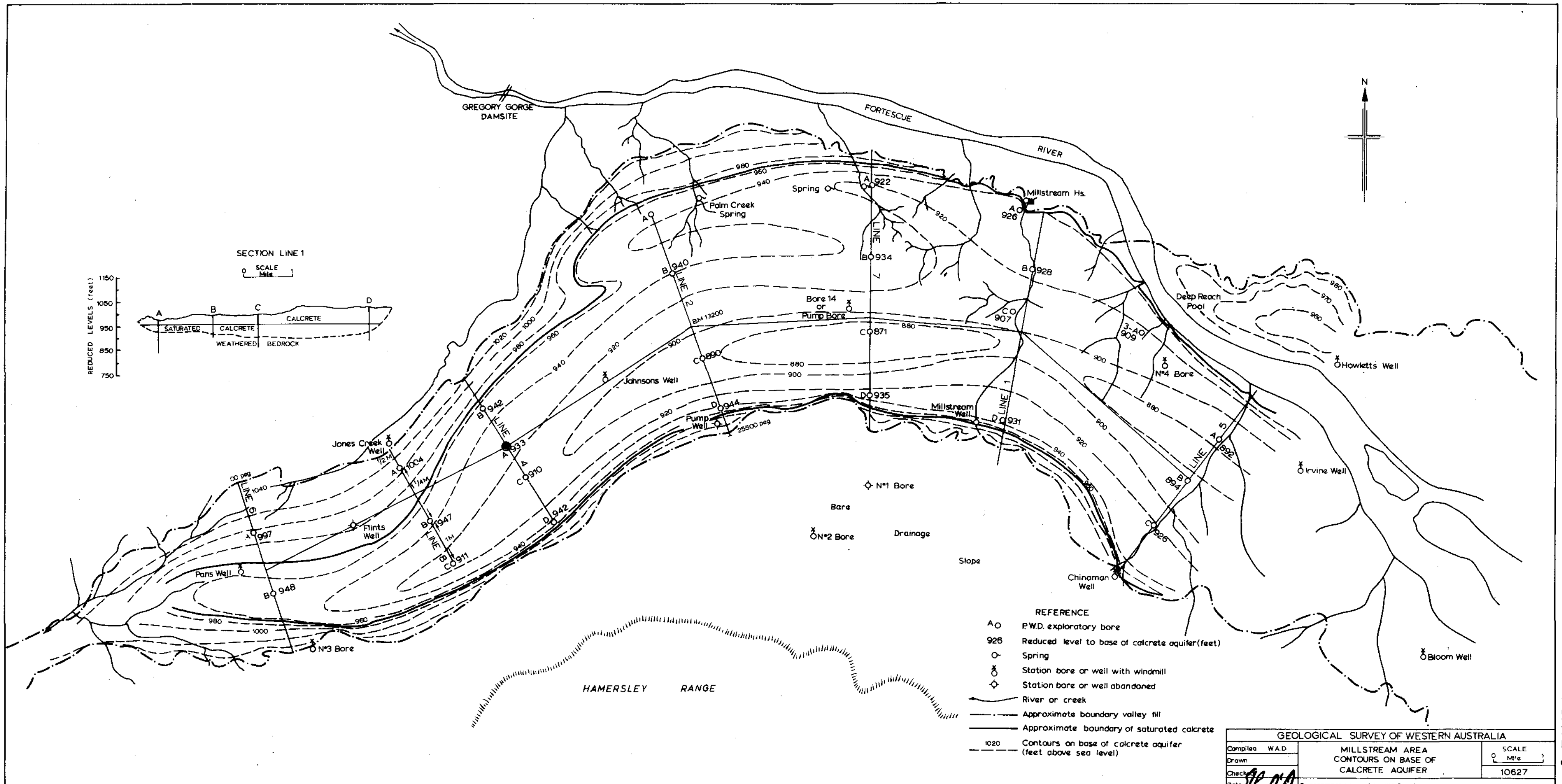
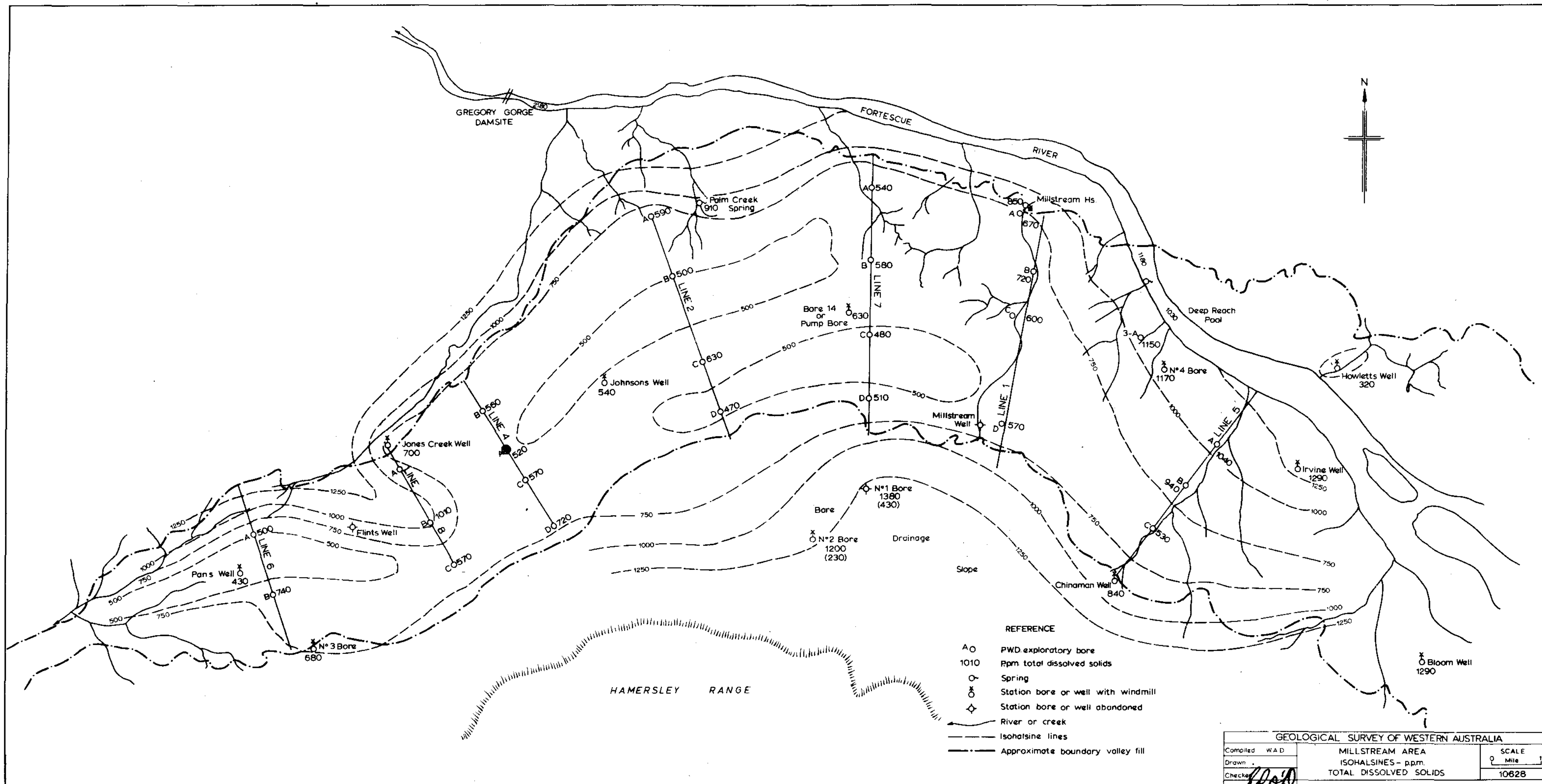

GREGORY GORGE DAMSITE
FORTESCUE
RIVER
N
Millstream Hs.
Palm Creek Spring
Spring
Bore 14 or Pump Bore
Deep Reach Pool
Howletts Well
Johnsons Well
Pump Well
Millstream Well
N°4 Bore
Jones Creek Well
Flints Well
Pans Well
N°1 Bore
N°2 Bore
N°3 Bore
Irvine Well
Chinaman Well
Bloom Well
Bare
Drainage
Slope
HAMERSLEY RANGE
BM 13200
25500 peg
00 peg
SECTION LINE 1
SCALE Mile
REDUCED LEVELS (feet)
1150
1050
950
850
750
A
B
C
D
SATURATED
CALCRETE
CALCRETE
WEATHERED
BEDROCK
LINE 1
LINE 2
LINE 3
LINE 4
LINE 5
LINE 6
LINE 7
A 922
B 934
C 871
D 935
A 926
B 928
C 907
D 931
3-A 909
A 892
B 894
C 926
B 940
C 890
D 944
B 942
A 933
C 910
D 942
A 1004
B 947
C 911
A 997
B 948
980
960
940
920
900
880
1000
1020
1040
970
REFERENCE
A○ P.W.D. exploratory bore
926 Reduced level to base of calcrete aquifer (feet)
Spring
Station bore or well with windmill
Station bore or well abandoned
River or creek
Approximate boundary valley fill
Approximate boundary of saturated calcrete
1020 Contours on base of calcrete aquifer (feet above sea level)
GEOLOGICAL SURVEY OF WESTERN AUSTRALIA
Compiled W.A.D.
Drawn
Checked
Date
MILLSTREAM AREA
CONTOURS ON BASE OF
CALCRETE AQUIFER
SCALE
Mile
10627
To accompany report by W.A. Davidson

PLATE 3

PLATE 4



GREGORY GORGE DAMSITE
FORTESCUE RIVER
Palm Creek Spring
Millstream Hs.
Deep Reach Pool
Howletts Well 320
Bore 14 or Pump Bore
Johnsons Well 540
Jones Creek Well 700
Flints Well
Pans Well 430
Nº 3 Bore 680
Nº 1 Bore 1380 (430)
Nº 2 Bore 1200 (230)
Millstream Well
Nº 4 Bore 1170
Irvine Well 1290
Chinaman Well 840
Bloom Well 1290
Bore Drainage Slope
HAMERSLEY RANGE
LINE 1
LINE 2
LINE 4
LINE 5
LINE 6
LINE 7
REFERENCE
PWD exploratory bore
1010 Ppm total dissolved solids
Spring
Station bore or well with windmill
Station bore or well abandoned
River or creek
Isohalsine lines
Approximate boundary valley fill
GEOLOGICAL SURVEY OF WESTERN AUSTRALIA
MILLSTREAM AREA
ISOHALSINES - p.p.m.
TOTAL DISSOLVED SOLIDS
SCALE
Mile
10628
Compiled W.A.D.
Drawn
Checked
Date
To accompany report by W.A. Davidson

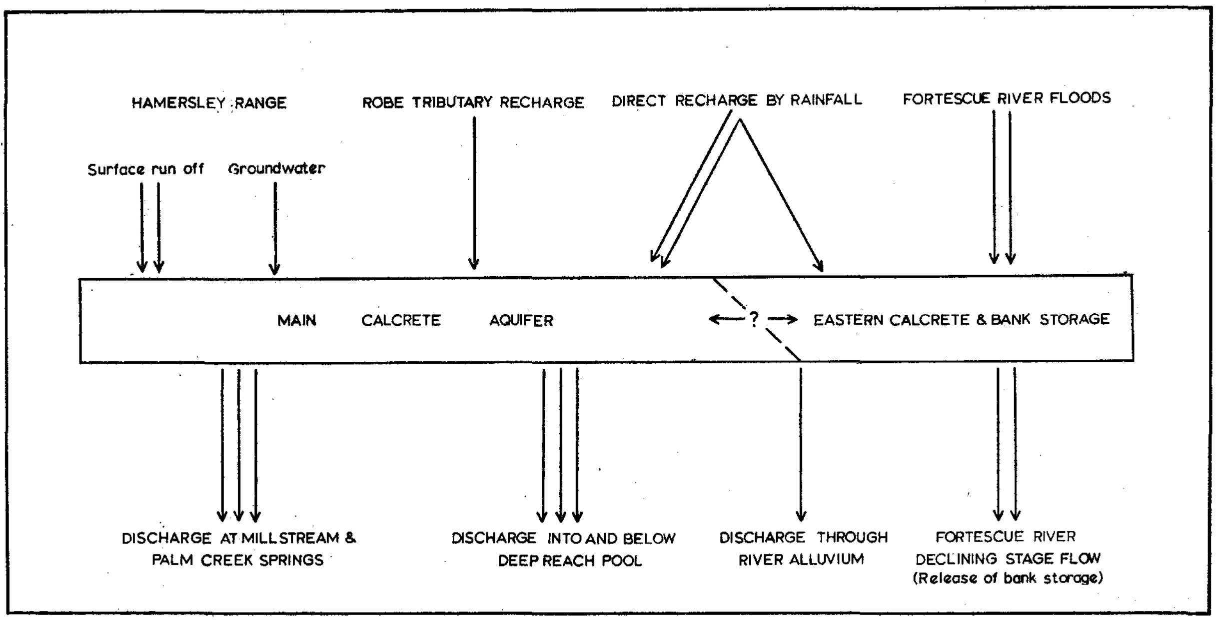


Figure 4. Millstream area, recharge—discharge relations.

GROUNDWATER RESOURCES

Recharge—discharge regime

The recharge—discharge regime is illustrated by Figure 4, the relative importance of each element being shown by one, two or three arrows.

During wet season conditions the hydraulic gradient in the vicinity of Deep Reach Pool would tend to flatten, as the water level in the river rose, to the extent of a possible reversal, in which case, recharge to the calcrete aquifer would take place. During dry season conditions the level of the pool would once more drop, the hydraulic gradient would steepen and discharge by springs from the calcrete would once more be established.

At the present water table level the Millstream calcretes must be regarded as an almost closed groundwater reservoir with limited inter-connection with the Fortescue River.

Natural discharge

Seasonal variations of discharge from the system as recorded by the Department of Public Works are as follows:

Date	Millstream Spring *Cusecs*	River Pools *Cusecs*	Total
16/5/64	6·20	10·35	16·55
2/6/65	7·64	6·31	13·95
11/1/68	9·70	....	....
15/4/68	8·33	9·53	17·86
15/5/68	7·94	....	16·83
1/6/68	....	8·89	....
3/7/68	8·93	....	....
10/8/68	7·42	....	....
3/9/68	8·75	10·14	18·89
30/10/68	6·65	9·04	15·69

The mean rate of discharge is about 16 cusecs per day or say 3,000 million gallons per annum.

Very minor discharge may also take place through the sands and gravels of the main Fortescue channel downstream of Deep Reach Pool.

Recharge

The overall general conclusion from the isohalsines is that there has been very little recharge to the calcrete body by groundwater movement from Proterozoic rocks and that most of the recharge has resulted from direct intake of rainfall, surface runoff from the Hamersley scarp, and groundwater movement from the southwest and northeast. Those areas of the calcrete aquifer which have been influenced by the infiltration of groundwater from the Proterozoic rocks have higher salinity counts. Some recharge to the calcrete by groundwater movement from the vicinity of station bore No. 1 may take place after heavy rains.

Groundwater storage

Large quantities of potable water are stored within the Millstream calcretes. Owing to the high porosity and permeability of the calcrete shown by small drawdown during uncontrolled pump-tests, a rough estimate of the storage coefficient may be made so that an approximate assessment of the total groundwater storage is possible. If a value of 20 per cent. is taken and applied to the estimated 80 square mile area over which the mean saturated calcrete thickness is about 30 feet, the volume of water stored becomes $80 \times 5280^2 \times 30 \times 0.2$ cubic feet, or approximately 80,000 million gallons. This is equivalent to approximately 25 times the total measured annual discharge at the surface.

An average discharge of 4 million gallons per day from Millstream Spring and 4 million gallons per day from surface flow downstream of Deep Reach Pool indicates that a total of 8 million gallons per day or roughly 3,000 million gallons per year discharges from the system, which corresponds to the annual recharge. Therefore, the maximum rate at which water may be withdrawn by pumpage without depleting storage is 8 million gallons per day, of which 4 million should come from the calcrete and 4 million from Deep Reach Pool. As the calcrete is probably a source of water to Deep Reach Pool a pumping rate in excess of 4 million gallons per day from the calcrete would tend to reduce leakage into the pool by a lowering of the hydraulic gradient. This could result in a lowering of the salinity of the mixture of water obtained from the two sources together.

If the estimated storage is 80,000 million gallons and the annual recharge is approximately 3,000 million gallons, a pumping rate of 19 million gallons per day will completely dewater the calcrete in about 20 years. However, if the storage coefficient in the lower parts of the aquifer is less than 0.2 dewatering will occur much sooner.

SUMMARY AND CONCLUSIONS

1. The Millstream calcretes provide a natural groundwater reservoir with limited inter-connection with the Fortescue River.

2. The areal extent of the calcrete aquifer although not fully known is at least 80 square miles, and for an assumed storage coefficient of 0.2 and an average thickness of 30 feet the trough contains approximately 80,000 million gallons.

3. Approximately 8 million gallons per day can be pumped from the aquifer without reducing the volume of water in storage, providing normal recharge takes place.

4. The trough is mainly recharged directly from rainfall and by surface runoff from the Hamersley Ranges.

5. The investigation is incomplete as the relationship between river flow and the groundwater body is still open to conjecture.

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Appendix 1

MILLSTREAM UNDERGROUND WATER PROJECT–GRAVITY SURVEY

by D. L. Rowston

A gravity survey of the Millstream area was made by the Geological Survey of Western Australia in the early stages of the underground water investigations in an attempt to detail the bedrock topography of the Fortescue valley, and thus delineate possible ancient river channels. Seismic refraction work was advocated as the most effective geophysical method of obtaining the information, but in the absence of suitable equipment the gravity survey was carried out as a second choice.

Prior to the recently completed exploratory drilling the Fortescue Valley was thought to be underlain by a southerly dipping sheet of Wittenoom Dolomite and infilled with alluvium containing some calcrete. It was therefore assumed that an adequate density contrast between bedrock and valley fill would apply and facilitate a simple and accurate interpretation of the results.

A total of 522 gravity observations were made at stations 300 feet apart along six traverses across the valley. The complementary topographic survey, necessary for the gravity reductions, also provided accurate locations and levels for the exploratory bores. Bouguer anomaly profiles were computed using elevation correction factors ranging from 0.06 to 0.073 mgl/ft. The latter value was adopted as near correct on the basis of least correlation with topography and is equivalent to a surface density of 1.6 gms/cc. Density measurements were also made on samples of the various rock types in the area.

Early drilling results from bores along Line 1 indicated that the original assumption could be erroneous, and the interpretation of the gravity profiles was re-oriented to satisfy the existing geological data. The correlation of gravity highs with the thicker calcrete suggested that the gravity configuration could be due to variations in the thickness of calcrete, and a model, based on the drilling information and not unreasonable density difference of 0.4 gm/cc., gave a theoretical curve in close agreement with the residual gravity profile. The remaining profiles were interpreted accordingly and presented in a preliminary report.

Whilst this plausible solution was substantiated in part by subsequent drilling many discrepancies between the bore data and gravity predictions indicate that the interpretation is far more complex than anticipated.

Strata logs of the bores show that many of the basic assumptions required for a simple interpretation are untenable. For instance, the weathered materials in which most bores terminated indicate that the bedrock is by no means uniform and may be derived from the Wittenoom Dolomite (2.68 gms/cc), Marra Mamba Iron Formation (2.53 gms/cc), or the Roy Hill Shale (2.28 gms/cc). Further, the calcrete which extends over most of the area, exhibits a variable composition ranging from the massive form, with a measured density of 2.51 gms/cc, to highly porous and water filled kankar with a bulk density perhaps as low as 1.6 gms/cc. As none of the bores penetrated fresh bedrock, the effects of the bedrock relief must also be added to the list of factors influencing the Bouguer gravity. These factors cannot be separated with any confidence and any interpretation of the gravity results must be considered highly speculative.

CONCLUSIONS

The relatively complex environment of the Millstream area precludes a realistic interpretation of the Bouguer gravity. Even with all the drilling information now available, it is not possible to reduce the number of variables to the stage where even qualitative predictions of the subsurface geology can be made. The failure of the method in this locality does not rule out its application elsewhere and each area should be considered on its own merits.

GEOLOGY AND EXCAVATION METHODS IN CUTTINGS

by F. R. Gordon

ABSTRACT

The manner in which a rock mass is excavated is strongly influenced by the site geology, especially the geological weaknesses. This affects the successful development of the site, which is critical in the case of highway or railway cuttings where close adherence to a designed shape is necessary for both economy and stability.

The slope of the cutting walls, the provision of benches or berms, and the digging of vertical-walled drainage ditches at the toe of the slope are all design matters for which geological conditions must be known. The presence of sheet and cross joints, and variations in weathering and rock type are masked geological defects which often have strong influence on the final shape of the excavation. The pattern of blast holes, the number of repeated shocks, and the technique of presplitting are blasting methods liable to cause damage if used in the wrong environment.

INTRODUCTION

A standard (4 foot 8½ inch) gauge railway 390 miles long is under construction from Kalgoorlie to Fremantle and Kwinana, through the iron ore deposits of Koolyanobbing. Most of the cuttings evaluated are situated on the Avon Valley Deviation which follows the Swan-Avon river valley through a dissected, uplifted, granite block of the Darling Range between Northam and Midland Junction (Gordon, 1968).

GEOLOGY AND PLANNING

Quarrying and cuttings

A railway cutting ideally has smooth slopes at precise angles, whereas in an open quarry the concern is to remove rock, not to shape walls. Contractors tend to regard a cutting as a quarry to supply rock to adjacent fills, and this fundamental difference in outlook means that the finished product is at best a compromise. The system of payment usually offers no incentives for precisely defined shapes, and bulk excavation methods modified by the skill and experience of the contractors' forces and the experience and persistence of the principals' representatives are all factors influencing the final shape.

Slope angles

The basis of selection of slope angles for various cuttings along the standard gauge route ranged from calculations by computors in London programmed on the notion of solid homogenous granite to full-scale joint surveys and rock-mechanics analysis. The use of rock-mechanics methods was tempered by the presence of folded structures, and of curved sheet joints not amenable to the mathematical methods available. A further insufficiency was the fact that rock-mechanics methods assumed no effect from blasting on slope stability. In practice this factor was often critical.

Berms

Berms are benches to arrest falling rock on a high slope. Their production proved a major problem because the berm surface once formed part of the floor of a higher lift damaged by blasting (rose of joints). Excavation of the lower lift has caused further breaks, and where the final shape has been achieved by trimming holes, the outer edge of the berm has been attacked three times. (Plate 6A.) Where sheet joints are within five feet of a berm, it is not possible to retain the berm; likewise where there is dominant local vertical jointing (Gordon, 1966).

Ditches

The provision of a drainage ditch immediately at the foot of a batter slope is a negation of the purpose of designing batter slopes at a certain angle, as the vertical slot over-steepens the toe at its weakest point (Gordon, 1967).

Conceptions

The quantity and quality of information available or gained by the contractor governs the method that is proposed, and thus the final cost of the work. Fundamental misconceptions are often made such as equating a museum specimen material 'granite' with the actual rock mass of varying composition, affected by weathering and with many structure defects. Initial engineering reconnaissances are often coloured by examining topographically prominent outcrops of resistant rock, whereas the weakest rocks are often not seen.

GEOLOGICAL STRUCTURES AND EXCAVATION

Influence of cross joints

Cross joints are steeply dipping joints that intersect the walls of the cutting at between 45° and 90°. Prominent joints striking across a cutting pose few problems if the joints are closed, and there are no intersections by other big joints. Control of open-cross-jointed rock is quite difficult, as the openings tend to channel the effect of the explosive, accentuating the opening, causing overbreak, and damaging the walls (Plate 5A).

A similar channelling effect occurs when prominent, cross joints are intersected. A 'toe' is often produced, and this is often subsequently reduced with further damage to the slope (Figure 5).

Influence of sheet joints

In Western Australia, sheet joints exercise a profound influence on the condition of granite masses, and on the stability of excavations in them (Gordon, 1968). A further effect of these master joints is on the control of blasting. The incidence of sheet joints is greatest close to the rock surface; in the first 5 feet joints may occur every foot. This means a restriction is imposed on the height to which a blast hole may be loaded. In addition, these joints control the movement of water through the rock mass, which in turn controls the amount of chemical weathering. If the lower joint surface is impervious, the rock between the rock surface and the joint may become completely weathered, leaving an abrupt transition to fresh rock. Alternately, the rock on either side of the joint plane may be completely reduced to a sandy clay, enclosed in only slightly weathered rock. Those near-horizontal differences in weathering mean that large overhangs are often developed on blasting, where softer rock is overshot, usually in the top 10 feet of the cutting (Plate 5B).

Sheet joints also often determine whether a berm or bench can be successfully produced.

Overshooting the toe of a batter

At the toe of a rock slope, either at the foot of a cutting or at a berm, there are high concentrations of stress. Consequently, weakening of the slope by overbreak and over-steepening accentuates the possibility of slope failure. Overshooting the toe may be caused by faulty excavation methods, or by unknown variations in site conditions, such as:

(1) the presence of softer bands of rock either as a change of rock type or from physical or chemical weathering, may allow the toe to be overshot;

(2) the blast holes may be overloaded or the blasting pattern unsuitable for the rock type, e.g. vertically foliated rock across the cutting will break back more readily than massive rock;

(3) the method of securing the shape may be faulty with regard to rock type, e.g. box excavation followed by angled trimming shots may be preferable to block excavation or pre-splitting. (Figure 6)

(4) a pre-existing structure may guide the explosive effect (Plate 6A);

(5) a slope may be left at an overflat angle because of layout or drilling variations, and later trimming shots of necessity make the lower part of the slope oversteep (Plate 6B);

(6) a vertical drainage ditch may be excavated at the toe of the slope.

Variations in rock type

Where the rock type is changing frequently, as in a vertical, banded gneiss sequence, the response of each rock type to a set pattern of blasting varies greatly. This means that if the pattern of holes and the loading are not varied, some of the bands will be overshot, with the batters sustaining damage, while in other sections, the rock may be undershot, leaving a toe, often to be reduced with further damage to the batter. The variety of rock types is often accentuated by chemical weathering, and folding, faulting, or jointing has often emphasised differences of mechanical properties.

During the early stages of excavation, it is not always possible to predict with certainty the composition and condition of the next slice to be excavated, and uniform loading of shot holes means that softer and weathered areas are overloaded and the batters are damaged. At depth, in a second lift for example, the nature of the rock to be excavated can often be predicted with some accuracy from observations of the cutting walls and floor, and overshooting can be minimized by lighter loading of holes and variations of the blast hole pattern.

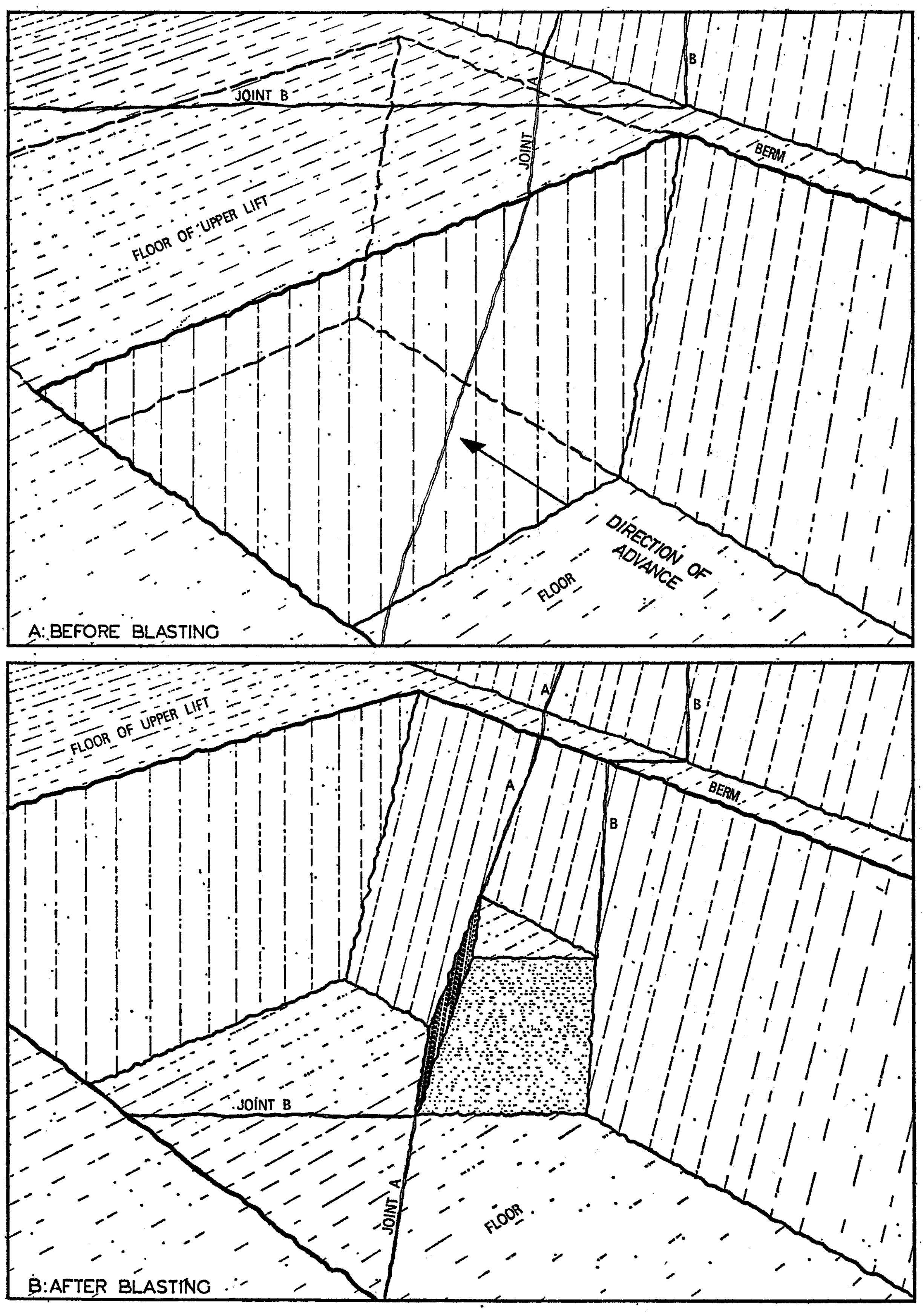


Figure 5. Toe formed by cross joints during cutting excavation. Standard Gauge Rail Project.

PLATE 5

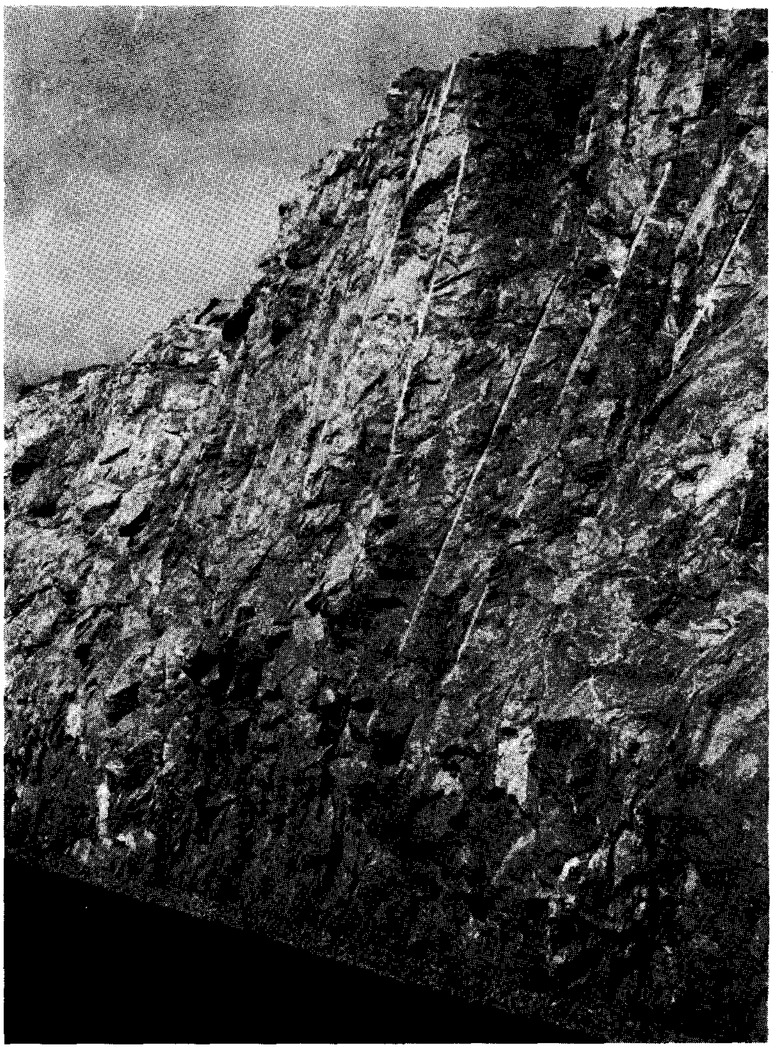
A. Overbreak caused by the channelling effect of open cross joints, in this case foliation joints; FN 1239.

B. Prominent sheeting causing large overhangs after blasting. Abrupt transition from weathered to fresh rock because of control of water movement on the top sheet joint; FN 1240.

PLATE 6

A. A steeply dipping joint plane has caused overbreak at the toe of a batter. Note also the loss of the berm edge, now filled with rubble, because of numerous blasting cycles; FN 1241.

B. Overflat slope has been reshot at toe to give proper clearance. Oversteep toe is now highly stressed; FN 1242.



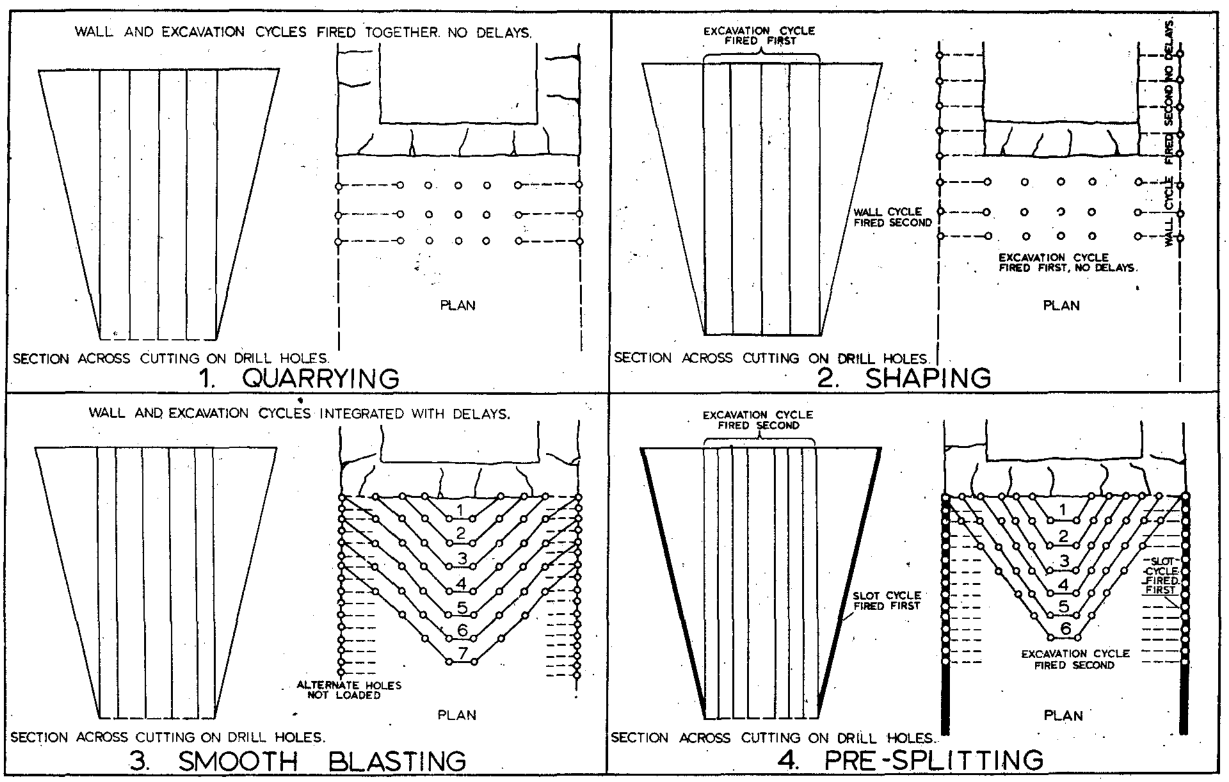


Figure 6. Standard Gauge Rail Project, methods of shaping cut walls. All numbers on the plans refer to millisecond delay intervals. (Drawing not to scale.)

BLASTING METHOD AND GEOLOGY

Variation of method

It has been emphasised that minor variations in the hole pattern and loading of holes are essential to meet the geological variations of a site. Changes in excavation methods are desirable and are often necessary where weathered rock may be removed with scrapers in the initial stages with a minimum of blasting. It is equally necessary to affirm that any major alteration to the blasting procedure should not be carried out until all the effects of site geology have been considered. The bottom lift of a deep cutting is no place for experiments, as the implications of failure are too serious.

Attempts are often made to retain scrapers by the increased use of explosives as fresher rock is encountered at depth. Often in the attempt to keep rock pieces at manageable size, the rock is overshot, and the slopes suffer.

Pre-splitting

Pre-splitting is a modern shaping technique in which the boundaries of the excavation are defined by a slot, blasted out before the site is excavated by normal methods. (Figure 6) The formation of an opening on the batter line undoubtedly serves to protect the face from damage resulting from the geological defects outlined above. However, in certain cases along the standard gauge route it was found that the formation of the slot caused such damage to the walls as to negate the benefits. This was particularly true in fresh, medium to fine-grained granite outcrops of small topographic relief, divided by defined sheet joints, where the pre-splitting method had to be discontinued. It was found that numerous individual blocks of rock, that either were separated by normal jointing or stood out from the cutting walls, had steeply dipping exfoliation-type cracks at the rear, parallel to the batter slope. It is not quite clear whether the cracking parallel to the initial shot was produced at the time of slot formation or not, but observation seems to indicate that these are post-excavation relaxation features.

Rock fabric and blasting repetition

When a choice of blasting patterns is available, consideration should be given to the nature of the rock fabric, and whether it would break down during several cycles of blasting, and thus make it preferable to shape and excavate in one operation, rather than with several. In the illustration, some of the blast-hole patterns used in excavating the railway cuttings on the standard gauge line are given (Figure 6).

In cut areas where the walls were of highly to moderately weathered granite, it was found that shaping and excavation were best done in one cycle, rather than by block excavation followed by shaping. Likewise, in outcrops of coarse-grained porphyritic granite, it was found that cracking of the quartz grains allowed accelerated breakdown of the rock under successive blasting cycles.

CONCLUSION

Geological factors must be taken into account during excavation of cuttings just as much as in the exploration, feasibility, and design stages. The problems created also call for further geological work during the maintenance period.

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REGIONAL GEOLOGICAL IMPLICATIONS, ROCKY POOL DAM SITE INVESTIGATIONS, CARNARVON BASIN.

by P. M. Hancock

INTRODUCTION

During 1967 a detailed mapping and auger-drilling programme was undertaken at Rocky Pool, Gascoyne River, by the Geological Survey in association with the Public Works Department (Hancock, 1968). In addition to information relevant to the appraisal of a dam site, several features of regional geological significance emerged from the investigation.

Except for the Toolonga Calcilutite and the Nadarra Formation all units described in this report are informal units.

CRETACEOUS—TERTIARY BOUNDARY

Continuous marine sedimentation from Upper Cretaceous into Paleocene times characterizes much of the western part of the Carnarvon Basin. However, at Rocky Pool and on Brickhouse Station no marine Tertiary material has been found, and unfossiliferous presumed-Tertiary sediments, probably of deltaic origin, unconformably overlie Upper Cretaceous (Campanian) marine clays, (Plate 7). At Rocky Pool an auger-drilling programme has demonstrated that the unconformity between the Campanian Toolonga Calcilutite and the overlying unfossiliferous presumed-Tertiary material is one of strong relief.

The presence of thin gypsum deposits overlying the thickest sections of the green clay (Kutg of Toolonga Calcilutite) at the dam site indicates an emergence of the marine sediments and the onset of arid, evaporative conditions similar to that of Lake MacLeod today. The green clay (Kutg) was probably eroded during the early Tertiary as a result of uplift and river rejuvenation. The unfossiliferous presumed-Tertiary sediments overlying the green clay are probably river alluvium.

ANTICLINE AT ROCKY POOL IN RELATION TO ANTICLINES FARTHER NORTH IN CARNARVON BASIN

The western central part of the Carnarvon Basin, which is bounded to the east by the Kennedy Range, has been subjected to north-south faulting along which the western blocks were downthrown as much as 10,000 feet after the Permian period but before the onset of Cretaceous times. During the Cretaceous period, marine sandstones, shales, and clays were deposited on the downfaulted blocks. Sedimentation continued with interruptions into the Tertiary period, with the deposition of marine and deltaic sediments. Late Cretaceous east-west compression which continued through Miocene to possibly Pleistocene and even post-Pleistocene times, reversed the original displacement, uplifting the western blocks. However the Upper Cretaceous, presumed-Tertiary, and probable Quaternary sediments which mantled the faulted older rocks were merely folded into superficial asymmetrical anticlines with north-south axes parallel to the strike of the underlying fault planes. Seismic investigations and exploratory drilling north of latitude 24° 30′S have found several asymmetrical anticlines, each one with a north-south axis parallel to and just west of a fault plane, showing reversal of movement by post-Late Cretaceous uplift. The anticlines generally have dips of up to 10° on the western flanks and steeper dips of up to 30° on the eastern flanks, with a core of Upper Cretaceous sediments, and envelopes of Tertiary and Quaternary sediments.

It seems likely that these superficial anticlines, which extend in en echelon arrangement from Cape Range to latitude 24° 30′ S, probably continue southwards at least to the Gascoyne River, but are masked by Pleistocene to Recent superficial cover.

The small anticline at Rocky Pool has not been previously recorded and is probably a part of the en echelon system. A line of travertine outcrops trends northeastwards from Rocky Pool for a distance of 30 miles, apparently representing a northeasterly continuation of the Rocky Pool anticline (Condon, 1962).

Future seismic work in this area should demonstrate a southerly continuation of the anticline system with axes subparallel to the coastline in the west, and parallel to the "Basement Ridge" (Condon, 1965) in the east.

CORRELATION OF THE BROWN SANDSTONE (QT) WITH THE NADARRA FORMATION

The brown sandstone unit (QT) has a lithology comparable with the type section of the Nadarra Sandstone as described by Condon, (1967). The Quaternary age of the Nadarra is in keeping with the stratigraphical position of the brown sandstone which unconformably overlies the folded lateritized red siltstone (Tk).

LATERITIZATION AT ROCKY POOL

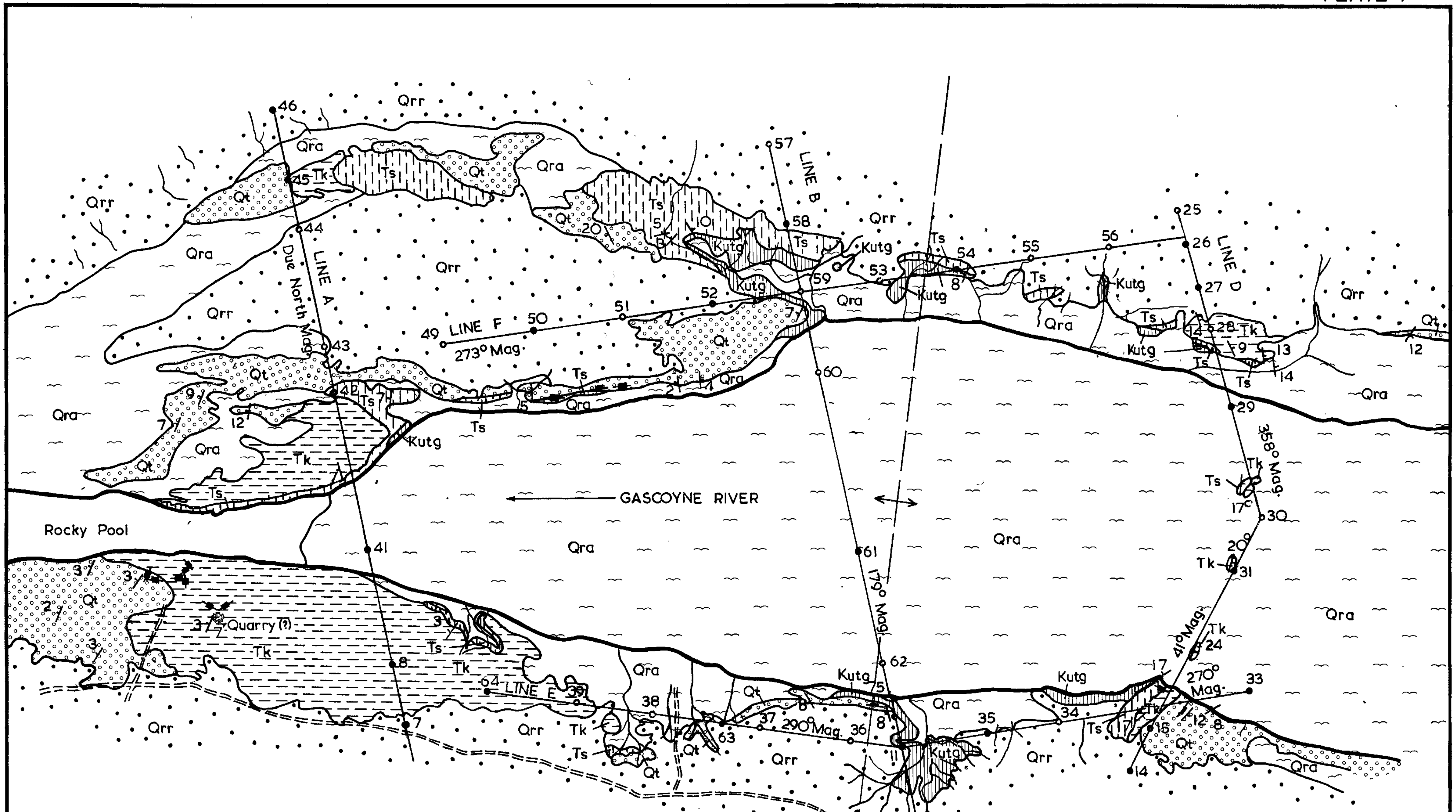
The presumed-Tertiary sediments at Rocky Pool demonstrate a lateritization profile with a lower pallid leached zone, an intermediate mottled zone, and an upper dark red lateritized ferruginous zone. Chemical analyses up the profile from the pallid leached zone to the lateritized ferruginous zone show an increase in iron from 1.81 to 4.18 per cent and aluminium from 2.01 to 6.20 per cent, and a reduction in silica from 89.4 to 74.8 per cent. Petrological examination of the lateritized red siltstone (Tk) and the white siltstone (Ts) reveals almost identical heavy mineral assemblages of detrital tourmaline and zircon, suggesting that these two units are the lateritized and leached equivalents of the same original siltstone.

The evidence suggests an upward movement of iron and aluminium to the lateritized zone from the pallid zone. The silica 'billy' capping on the lateritized siltstone suggests an upward movement of silica from that bed.

The red lateritized siltstone unit (Tk) becomes a leached white siltstone where it dips below the present-day water table, while the overlying silty soils appear to be undergoing present-day lateritization. This suggests the formation of the lateritized red siltstone (Tk) by an upward movement of aluminium and iron in solution, with the base of the lateritized zone corresponding with the lowest seasonal level of the water table.

The fact that the lateritization of the siltstone pre-dates the folding of the anticline is shown by boudins, necking, and shearing-out of beds caused by the differential movement of the competent lateritized red siltstone (Tk) over the relatively incompetent white siltstone (Ts). Where differential movement has caused shearing along the contact between the pallid white siltstone and the lateritized red siltstone, the intermediate mottled zone is thinned or absent. A low-angle shear zone on the left bank of the Gascoyne River at line D, which was probably caused by a differential movement on the steeply dipping eastern limb of the asymmetrical anticline, cuts both the pallid white siltstone and the lateritized red siltstone. Thus, plastic and brittle deformation caused by fold movements post-date the lateritization. The lateritization has increased the relative competency of the lateritized zone at the expense of the now less competent underlying pallid zone. Furthermore, the leaching out of the lateritized red siltstone to a pallid siltstone where it dips below the present water table, and the angular uncomformity between the laterized red siltstone (Tk) and the overlying brown sandstone (Qt), indicates that at least one period of anticlinal folding occurred after the lateritization of the siltstone.

The brown sandstone (Qt) on the eastern limb of the anticline dips at 8° to 12°, while the lateritized red siltstone, which it overlies, dips at 14° to 24°. This suggests a second and later period of folding of the laterized red siltstone.



REFERENCE

QUATERNARY
- Qra — Red, yellow, sandy, silty river deposits thin, red, silty, alluvial cover.
- Qrr — Red, silty, sandy dune material; thin pebble wash and consolidated soil cover.
- Qt — Brown sandstone and grit with minor conglomerate

UNCONFORMITY

TERTIARY
- Tk — Lateritized red siltstone (lateritized zone)
- Ts — White siltstone (pallid zone)

UNCONFORMITY

CRETACEOUS
- Kutg — Green calcilutite clay

SYMBOLS

- Anticlinal axis
- 12 Bedding—strike and dip
- 80 Jointing—strike and dip
- Outcrop boundary
- o 46 P.W.D. Gemco auger drillhole—Proposed
- • 46 P.W.D. Gemco auger drillhole—Completed
- Depression showing depth
- Track

GEOLOGICAL SURVEY OF WESTERN AUSTRALIA

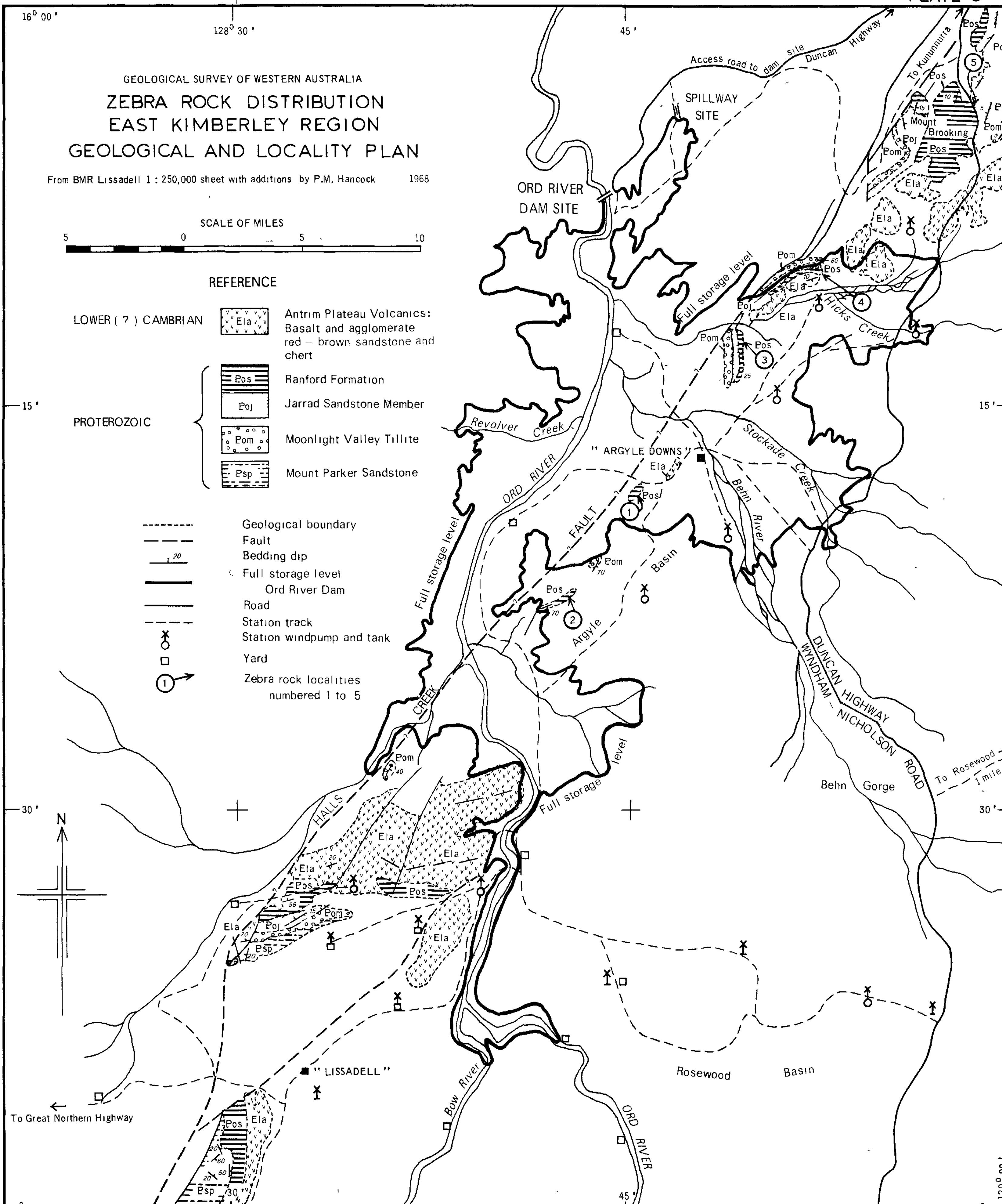
ROCKY POOL DAM SITE
SIMPLIFIED GEOLOGICAL PLAN

To accompany report by P.M. Hancock, 1968.

SCALE OF FEET

600 300 0 600 1200

10751


GEOLOGICAL SURVEY OF WESTERN AUSTRALIA
ZEBRA ROCK DISTRIBUTION
EAST KIMBERLEY REGION
GEOLOGICAL AND LOCALITY PLAN
From BMR Lissadell 1 : 250,000 sheet with additions by P.M. Hancock 1968
SCALE OF MILES
5 0 5 10
REFERENCE
LOWER (?) CAMBRIAN
Ela
Antrim Plateau Volcanics: Basalt and agglomerate red – brown sandstone and chert
PROTEROZOIC
Pos
Ranford Formation
Poj
Jarrad Sandstone Member
Pom
Moonlight Valley Tillite
Psp
Mount Parker Sandstone
Geological boundary
Fault
Bedding dip
Full storage level Ord River Dam
Road
Station track
Station windpump and tank
Yard
Zebra rock localities numbered 1 to 5
16° 00'
128° 30'
45'
15'
30'
16° 45
129° 00'
16° 45'
N
ORD RIVER DAM SITE
SPILLWAY SITE
Access road to dam site
Duncan Highway
To Kununurra
Mount Brooking
Full storage level
Hicks Creek
Revolver Creek
ORD RIVER
" ARGYLE DOWNS "
Stockade Creek
Behn River
FAULT
Argyle Basin
HALLS CREEK
DUNCAN HIGHWAY
WYNDHAM - NICHOLSON ROAD
To Rosewood 1 mile
Behn Gorge
" LISSADELL "
To Great Northern Highway
Bow River
Rosewood Basin
ORD RIVER

The age of the folding, if identified, would restrict the age range of lateritization and vice versa. Evidence from Giralia and Marrilla anticlines suggests up to four periods of folding viz (1) between upper Eocene and lower Miocene, (2) during lower Miocene, (3) between lower Miocene and Pleistocene, (4) and in the Pleistocene or post-Pleistocene time. If any of these fold movements were synchronous with the folding at Rocky Pool, then folding of the Quaternary brown sandstone (Qt) would have been in the Pleistocene or post-Pleistocene.

In the Carnarvon Basin lateritization is considered to have commenced in mid-Eocene (Condon, 1967), thus accommodating a folding of the lateritized red siltstone (Tk) in post-Eocene times.

The major fold movements at Cape Range and Rough Range, and Giralia and Marrilla anticlines, occurred between the Pliocene and post-Pleistocene periods, that is in the latter part of the lower Miocene—Pleistocene (3), and during the Pleistocene—post-Pleistocene (4) periods of folding. A major fold movement is required to account for the plastic and brittle deformation of the sediments at Rocky Pool. If the brown sandstone (Qt) which unconformably overlies the lateritized red siltstone (Tk) was folded during the Pleistocene—post-Pleistocene (4), then the siltstone (Tk) was probably initially folded in the latter part of the lower Miocene—Pleistocene period.

There is no suggestion or evidence of more than two periods of Tertiary—Quaternary folding at Rocky Pool, and it is probable that only the last two of the above four periods of folding affected the area. Thus the lateritization of the siltstone (Tk) predates a folding which appears to have occurred during the latter part of period (3) above, namely between Pliocene and post-Pleistocene.

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LOCATION AND INVESTIGATION OF ZEBRA ROCK OCCURRENCES, EAST KIMBERLEY REGION

by P. M. Hancock

INTRODUCTION

Zebra rock from Argyle Downs Station provides the basis for a small but valuable souvenir and jewellery industry which is mainly centred at Kununurra. The striking, red and white banded rock presents interesting problems concerning its formation and distribution. It is currently believed that the known occurrences of zebra rock will be submerged beneath the full storage level of the Ord River dam. However, as shown on the accompanying plate, most of the occurrences will remain above water.

The Ranford Formation (Dunnet and Plumb, 1964), which contains the zebra rock, was traced along its strike for 35 miles in a south-easterly direction from Mount Brooking. The known occurrences 1, 2, and 5 (as marked on Plate 8) were located and examined, and two further occurrences, marked 3 and 4, were discovered.

During the dry season, localities 1 and 2 are accessible by graded track, and localities 3 and 4 can be reached by four-wheel-drive vehicle. Locality 5 is on a scarp slope alongside the Duncan Highway. Zebra rock may occur in the southern continuation of the Ranford Formation on to Lissadell station, an area normally accessible during the dry season from the Great Northern Highway. It is also likely that the Ranford Formation occurs north-northeastward from Mount Brooking on Newry Station in the Northern Territory.

PREVIOUS RECORDINGS AND INVESTIGATIONS

Specimens of zebra rock were described by Blatchford (1927), Larcombe, (1925 and 1927), and Hobson (1930). Blatchford thought that the banding could be explained by a leaching out of iron oxide to produce white bands from an originally all red rock, but Larcombe invoked a deposition of alternate layers of ferruginous and non ferruginous material. Hobson refuted Larcombe's explanation on the grounds that the heavy minerals present in the rock are not concentrated in the red bands. He gave a detailed petrological description of several selected specimens and chemical analyses illustrating the similar composition of red and white bands, apart from a 5:1 iron ratio in favour of the red bands.

Geidans (written communication) working mainly on specimens from the Geological Survey of Western Australia and on some held at the University of Western Australia, suggested that the banding was due to ripple marking, with iron-rich detrital particles accumulating in ripple mark troughs by gravitational separation. He explained the branching and break up of the red beds into rods and blebs by the irregular pattern made by troughs of ripple marks on a sea floor.

OBSERVATIONS ON THE FIELD OCCURRENCE AND DISTRIBUTION OF ZEBRA ROCK

Attempts to explain the formation of banding features in zebra rock appear to have been based on the examination of selected hand specimens. The investigation of the rock 'in situ', and its field relationships, produces evidence which renders previous explanations largely untenable.

Zebra rock occurs as sparsely distributed elongate lenses in the upper part of the Ranford Formation, which consists of thinly bedded to finely laminated ferruginous siltstone and fine-grained ferruginous sandstone. The extremely fine bedding is even and continuous, and no ripple marks were found. The lenses are up to 2 feet thick and 10 to 20 feet long, and taper laterally into dark red-brown to purple-brown siltstone or sandstone. Bedding planes are continuous laterally from the zebra rock lenses into the surrounding rock. The iron-rich bands are mainly parallel or subparallel to bedding, but occasionally the banding is broken into rods, blebs, and short bands almost perpendicular to the main banding. It is significant that these deviations away from the main banding occur in the vicinity of joint planes and are aligned parallel or subparallel to those joint planes. It is apparent from field evidence that the disposition of the bands has been controlled by bedding and joint planes, which are the only major physical anisotropic features in this rock.

The red and white banding can be seen to merge laterally and vertically into red-brown or purple-brown rock, uniform apart from small pallid lenses up to an inch long, and significantly not the same colour as the red bands. It is thus unlikely that the red and white bands are representative of the original colouring or composition of the rock, and it is suggested that there has been a post-depositional mobilisation and concentration of iron by rhythmic precipitation from a pervasive aqueous-colloidal pore solution, controlled by bedding and joint planes.

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PETROLEUM EXPLORATION IN WESTERN AUSTRALIA IN 1968

by P. E. Playford and G. H. Low

INTRODUCTION

The principal events in oil exploration in Western Australia during 1968 were the discovery of gas at Mondarra in the Perth Basin and of oil in Legendre No. 1, the first offshore well in Western Australian waters, on the Northwest Shelf. The Mondarra gas field may have commercial prospects, but it seems that at present Legendre is non-commercial.

The amount of exploratory drilling during 1968 increased as compared with the previous year, though the number of wells completed was less. A total of 10 test wells and 14 stratigraphic wells were completed in 1968 and 4 test wells were drilling on December 31. The total footage amounted to 164,637 feet. This compares with 17 test wells and 11 stratigraphic wells completed, and a total footage of 115,970 feet in 1967.

Geophysical exploration during the year was at a lower level than in 1967. Seismic operations amounted to 19.62 party months (land) and 17.65 party months (marine) during 1968 compared with 53.4 party months (land) and 15.0 party months (marine) the previous year. During 1968, 4.42 party months of gravity surveys were conducted compared with 14.25 party months in 1967. No aero-magnetic surveys were carried out, but 3.69 party months of magneto-telluric surveys were conducted, compared with 6,478 line miles of aero-magnetic surveys and no magneto-telluric surveys in 1967. Field geological surveys increased from 22.5 geologist-months in 1967 to 30.0 in 1968.

OIL HOLDINGS

The positions of offshore exploration permits at the end of 1968 are shown on Plate 10. Details of these concessions are as follows:

Exploration Permits

Number	No. of graticular sections*	Expiry date of current term	Registered holder or applicant
WA-1-P	364	14/11/74	Woodside (Lakes Entrance) Oil Co. N.L., Shell Development Australia Pty Ltd, B.O.C. of Australia Ltd
WA-2-P	381	14/11/74	West Australian Petroleum Pty Ltd
WA-7-P	135	pending	do. do. do.
WA-8-P	18	pending	Coastal Petroleum N.L.
WA-9-P	56	pending	do. do.
WA-10-P	36	pending	do. do.
WA-12-P	5	pending	Associated Australian Oilfields N.L.
WA-13-P	387	29/8/74	West Australian Petroleum Pty Ltd
WA-14-P	396	29/8/74	do. do. do.
WA-15-P	352	pending	Australian Aquitaine Petroleum Pty, Arco Limited
WA-16-P	354	pending	do. do. do.
WA-17-P	379	pending	do. do. do.
WA-18-P	322	pending	do. do. do.
WA-19-P	142	pending	Alliance Oil Development Australia N.L.
WA-20-P	34	10/10/74	West Australian Petroleum Pty Ltd
WA-21-P	239	14/11/74	do. do. do.
WA-22-P	81	3/10/74	do. do. do.
WA-23-P	398	3/10/74	do. do. do.
WA-24-P	208	17/10/74	do. do. do.
WA-25-P	256	16/10/74	do. do. do.
WA-26-P	400	22/12/74	Canadian Superior Oil (Aust.) Pty Ltd, Australian Superior Oil Company Ltd, Phillips Australian Oil Company, Sunray D.X. Oil Company
WA-27-P	294	pending	do. do. do.
WA-28-P	375	pending	Woodside (Lakes Entrance) Oil Company No Liability, Shell Development (Australia) Proprietary Ltd, B.O.C. of Australia Ltd
WA-29-P	400	pending	do. do. do.
WA-30-P	400	pending	do. do. do.
WA-31-P	400	pending	do. do. do.
WA-32-P	395	pending	do. do. do.
WA-33-P	389	pending	do. do. do.
WA-34-P	397	pending	do. do. do.
WA-35-P	400	pending	do. do. do.
WA-36-P	57	pending	do. do. do.
WA-37-P	118	pending	do. do. do.
WA-39-P	104	pending	BP Petroleum Development Australia Pty Ltd, Abrolhos Oil N.L.
WA-40-P	102	pending	BP Petroleum Development Aust. Pty Ltd, Hawkstone Minerals Ltd
WA-41-P	33	pending	Coastal Petroleum N.L.

* A 'Graticular Section' is a rectangular area of 5 minutes latitude by 5 minutes longitude and of approximately 25 square miles extent.

Permits to Explore

Number	Area (square miles)	Expiry date of current term	Registered holder or applicant
27H	12,900	31/12/68	West Australian Petroleum Pty Ltd
28H	15,100	31/12/68	do. do. do.
30H	82,500	31/12/68	do. do. do.
106H	11,800	28/9/69	Westralian Sands Limited
127H	7,250	28/3/69	Alliance Oil Development Australia N.L.
151H	10,710	7/2/69	Beach-General Exploration Pty Ltd
152H	8,720	7/2/69	do. do. do.
153H	9,770	7/2/69	do. do. do.
172H	6,150	30/3/69	Coastal Petroleum N.L.
173H	12,250	30/3/69	do. do.
174H	6,100	30/3/69	do. do.
175H	4,100	30/3/69	do. do.
177H	6,050	30/3/69	do. do.
193H	2,750	5/2/69	Hawkstone Minerals Ltd, BP Petroleum Development Australia Pty Ltd
205H	16,700	17/9/69	Alliance Petroleum Australia N.L.
213H	10	20/6/69	Woodside (Lakes Entrance) Oil Co. N.L., B.O.C. of Aust. Ltd, Shell Development (Aust.) Pty Ltd
217H	3,350	30/5/68	West Australian Petroleum Pty Ltd
221H	950	28/7/68	Australian Aquitaine Petroleum Pty Limited, Arco Ltd
226H	31,900	6/4/68	West Australian Petroleum Pty Ltd
227H	11,400	6/4/68	do. do. do.
228H	2,200	13/5/68	do. do. do.
235H	19,850	21/1/69	Canadian Superior Oil (Aust.) Pty Ltd
236H	2,600	3/2/69	Abrolhos Oil No Liability, BP Petroleum Development Aust. Pty Ltd
238H	1,190	9/1/69	B.O.C. of Australia Ltd, Shell Development (Aust.) Pty Ltd, Woodside (Lakes Entrance) Oil Co. N.L.
240H	3,050	14/6/69	Coastal Petroleum N.L.
251H	4,228	28/6/69	West Australian Petroleum Pty Ltd
253H	5,200	28/12/68	Westralian Sands Limited
259H	12,930	1/2/69	West Australian Petroleum Pty Ltd
260H	5,860	19/4/69	do. do. do.
261H	3,000	19/4/69	do. do. do.
263H	30	11/6/70	Associated Aust. Oilfields N.L.

Licenses to Prospect.

Number	Area (square miles)	Expiry date of current term	Registered holder or applicant
108H	200·000 (excluding Lyndon Loc. 42)	17/1/69	West Australian Petroleum Pty Ltd
111H	150·000	4/6/69	do. do. do.
115H	200·000	5/11/68	do. do. do.
119H	109·032	12/1/69	do. do. do.
121H	120·000	11/7/69	do. do. do.
122H	113·418	11/7/69	do. do. do.
123H	113·232	11/7/69	do. do. do.
124H	112·528	20/4/69	do. do. do.
125H	112·477	20/4/69	do. do. do.
126H	200·000	8/2/69	do. do. do.
130H	189·929	8/3/69	do. do. do.
132H	200·001	13/5/69	do. do. do.
133H	200·001	13/5/69	do. do. do.
140H	198·750	17/5/69	do. do. do.
145H	187·411	17/5/69	do. do. do.
146H	187·032	17/5/69	do. do. do.
147H*	135·500	17/5/69	do. do. do.
149H	200·000	14/7/69	do. do. do.
150H	200·000	18/10/69	do. do. do.
151H	194·367	5/7/69	do. do. do.
154H	160·200	13/12/68	Beach-General Exploration Pty Ltd
158H*	0·960	20/3/69	West Australian Petroleum Pty Ltd
159H*	1·440	20/3/69	do. do. do.
160H*	0·400	20/3/69	do. do. do.
161H*	8·960	20/3/69	do. do. do.
162H*	0·480	20/3/69	do. do. do.
163H*	0·320	20/3/69	do. do. do.
164H*	2·500	20/3/69	do. do. do.
165H*	1·920	20/3/69	do. do. do.
169H*	0·320	20/3/69	do. do. do.
171H	190·000	14/4/69	do. do. do.
172H	199·697	21/6/69	do. do. do.
173H*	2·200	9/8/68	do. do. do.
174H	190·000	28/7/69	do. do. do.
175H	200·000	10/8/69	do. do. do.
177H	200·000	20/12/69	do. do. do.
184H	200·000	4/4/69	do. do. do.
185H*	5·600	26/7/69	do. do. do.
186H*	7·040	14/8/69	do. do. do.
187H	193·440	13/8/69	do. do. do.
190H	100·000	2/10/69	do. do. do.
191H*	0·800	16/10/69	do. do. do.
192H	130·000	28/2/70	do. do. do.
195H*	6·560	16/1/70	do. do. do.
196H	150·640	11/3/70	do. do. do.
198H	197·980	27/2/70	do. do. do.
199H	200·000	8/8/70	Beach-General Exploration Pty Ltd

Licenses to Prospect—continued

Number	Area (square miles)	Expiry date of current term	Registered holder or applicant
200H	197·000	27/3/70	West Australian Petroleum Pty Ltd
202H*	0·320	27/3/70	do. do. do.
203H*	1·600	27/3/70	do. do. do.
204H*	6·880	27/3/70	do. do. do.
213H	196·418	27/3/70	do. do. do.
215H	199·961	7/10/70	do. do. do.
216H	198·372	7/10/70	do. do. do.

* Only the onshore area has been given for these Licenses to Prospect which are affected by Exploration Permits.

Petroleum Leases

Number	Area (square miles)	Expiry date of current term	Holder
1H	100	2/2/88	West Australian Petroleum Pty Ltd
2H	100	2/2/88	do. do. do.

DRILLING

The positions of wells drilled for petroleum exploration in Western Australia to the end of 1968 are shown on Plates 9, 11. Drilling was carried out during the year on the following permits:

EXPLORATION PERMIT WA-1-P

Exploration Permit WA-1-P (offshore) is held by Woodside (Lakes Entrance) Oil Co. N.L., Shell Development Australia Pty. Ltd., and B.O.C. of Australia Ltd., B.O.C. being the operating company. The permit covers the northernmost part of the Carnarvon Basin, on the Northwest Shelf. The first offshore well in Western Australian waters, Legendre No. 1, was drilled on this concession during the year. Oil flowed at a maximum rate of 1,014 bbl/day with 0.11 mmcf/day of gas on a drill-stem test of the interval 6,211-6,227 feet in Lower Cretaceous rocks of the "Barrow Group". However, the producing sand is thin and it is unlikely that the field can be developed commercially at this time. Details of the well are as follows:

Lengendre No. 1

Type: Test well.

Latitude and Longitude: 19° 40′ 16″S, 116° 43′ 57″E.

Elevation: W. D. — 170 feet, R. T. + 30 feet.

Commenced: 7th June, 1968.

Completed: 17th November, 1968.

Total depth: 11,393 feet.

Bottomed in: Jurassic.

Status: Non-commercial oil well, plugged and abandoned. A drill stem test of the interval 6,211 to 6,227 feet flowed oil at 1,014 bbl/day and gas at 0.11 mmcf/day through a 24/64-inch choke.

EXPLORATION PERMIT WA-13-P

Exploration Permit WA-13-P is held by West Australian Petroleum Pty. Ltd., and covers part of the offshore Perth Basin. The company commenced drilling an offshore well, Gage Roads No. 1, on this concession during 1968. Details are as follows:

Gage Roads No. 1

Type: Test well.

Latitude and Longitude: 31° 57′ 20″S, 115° 22′ 33″E.

Elevation: W. D. — 191 feet, R. T. + 70 feet.

Commencement: 27th December, 1968.

Status: Drilling at 6,976 feet on 31st December.

EXPLORATION PERMIT WA-14-P

Exploration Permit WA-14-P is held by West Australian Petroleum Pty Ltd and covers part of the offshore Perth Basin. The company drilled its first offshore well, Quinn's Rock No. 1, on this concession during 1968. It was dry and was plugged and abandoned. Details are as follows:

Quinn's Rock No. 1

Type: Test well.

Latitude and Longitude: 31° 48′ 01″S, 115° 30′ 52″E.

Elevation: W. D. — 133 feet, R. T. + 79 feet.

Commenced: 10th October, 1968.

Completed: 11th December, 1968.

Total depth: 7,248 feet.

Bottomed in: Lower Cretaceous or Upper Jurassic.

Status: Dry, plugged and abandoned.

EXPLORATION PERMIT WA-28-P

Exploration Permit WA-28-P is held by Woodside (Lakes Entrance) Oil Co. N. L., Shell Development Australia Pty Ltd., and B. O. C. of Australia Ltd., B. O. C. being the operating company. The permit covers part of the Northwest Shelf and includes parts of the offshore Carnarvon and Canning Basins. The company commenced drilling an offshore well, Dampier No. 1, on this concession during the year. Details are as follows:

Dampier No. 1

Type: Test well.

Latitude and Longitude: 19° 52′ 42″S, 166° 00′ 45″E.

Elevation: W. D. — 250 feet, R. T. + 30 feet.

Commenced: 23rd November, 1968.

Status: Drilling at 8,611 feet on 31st December.

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 drilled two test wells, Dongara No. 7 and Mondarra No. 1, and commenced a third, Mondarra No. 2 during the year. Dongara No. 7 was dry, and Mondarra No. 1 was completed as a gas well in the 'Lower Triassic Sand'. Strong hopes are held that Mondarra will be developed as a commercial field, and the results of the second well are awaited with interest. Details of the wells are as follows:

Dongara No. 7

Type: Test well.

License to Prospect: 171H.

Latitude and Longitude: 29° 18′ 36″S, 115° 01′ 38″E.

Elevation: G. L. 141 feet, R. T. 154 feet.

Commenced: 24th July, 1968.

Completed: 21st August, 1968.

Total depth: 7,100 feet.

Bottomed in: Lower Permian.

Status: Dry, plugged and abandoned.

Mondarra No. 1

Type: Test well.

License to Prospect: 171H.

Latitude and Longitude: 29° 18′ 51″S, 115° 06′ 55″E.

Elevation: G. L. 259 feet, D. F. 273 feet.

Commenced: 9th October, 1968.

Completed: 25th November, 1968.

Total depth: 10,049 feet.

Bottomed in: Lower Permian.

Status: Gas well. A drill stem test of the interval 8,822-8,860 feet flowed gas at 10mmcf/day on ⅜-inch choke.

Mondarra No. 2

Type: Test well.

License to Prospect: 171H.

Latitude and Longitude: 29° 21′ 07″S, 115° 06′ 05″E.

Elevation: G. L. 87 feet, R. T. 101 feet.

Commenced: 20th December, 1968.

Status: Drilling at 6,783 feet on 31st December, 1968.

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 drilled two test wells and three stratigraphic wells in the permit area during 1968. All were dry and were plugged and abandoned, although a minor amount of oil was obtained in Thevenard No. 1. Details of these wells are as follows:

Hope Island No. 1

Type: Stratigraphic Well.

License to Prospect: 196H.

Latitude and Longitude: 22° 09′ 34″S, 114° 28′ 35″E.

Elevation: G. L. 16 feet, R. T. 30 feet.

Commenced: 26th February, 1968.

Completed: 13 March, 1968.

Total depth: 4,680 feet.

Bottomed in: Lower Permian.

Status: Dry, plugged and abandoned.

Observation No. 1

Type: Stratigraphic well.

License to Prospect: 195H.

Latitude and Longitude: 21° 44′ 28″S, 114° 32′ 12″E.

Elevation: G. L. 16 feet, R. T. 30 feet.

Commenced: 31st December, 1967.

Completed: 14th February, 1968.

Total depth: 7,510 feet.

Bottomed in: Middle Triassic.

Status: Dry, plugged and abandoned.

Sandy Point No. 1

Type: Test well.

License to Prospect: 192H.

Latitude and Longitude: 22° 25′ 50″S, 113° 47′ 46″E.

Elevation: G. L. 366 feet, R. T. 378 feet.

Commenced: 30th November, 1967.

Completed: 31st January, 1968.

Total depth: 9,992 feet.

Bottomed in: Lower Jurassic.

Status: Dry, plugged and abandoned.

Thevenard No. 1

Type: Test well.

License to Prospect: 164H.

Latitude and Longitude: 21° 27′ 45″S, 115° 01′ 05″E.

Elevation: G. L. 16 feet, R. T. 30 feet.

Commenced: 28th March, 1968.

Completed: 28th April, 1968.

Total depth: 6,810 feet.

Bottomed in: Upper to Middle Jurassic.

Status: Minor oil and gas shows, plugged and abandoned. A drill stem test of the interval 5,101-5121 feet recovered approximately half a gallon of oil.

Urala No. 1

Type: Stratigraphic well.

License to Prospect: 187H.

Latitude and Longitude: 21° 49′ 06″S, 114° 43′ 22″E.

Elevation: G. L. 7 feet, R. T. 12 feet.

Commenced: 15th September, 1968.

Completed: 7th October, 1968.

Total depth: 2,500 feet.

Bottomed in: Upper Triassic.

Status: Dry, plugged and abandoned.

PERMIT TO EXPLORE 30H

Permit to Explore 30H is held by West Australian Petroleum Pty Ltd and covers part of the Canning Basin. The company drilled one test well and two stratigraphic wells in this permit during 1968. All were dry and were plugged and abandoned. Details are as follows:

Chirup No. 1

Type: Stratigraphic well.
License to Prospect: 212H.
Latitude and Longitude: 19° 15′ 00″S, 120° 26′ 00″E.
Elevation: G. L. 10 feet, R. T. 15 feet.
Commenced: 26th August, 1968.
Completed: 7th September, 1968.
Total depth: 2,502 feet.
Bottomed in: Lower Permian.
Status: Dry, plugged and abandoned.

Doran No. 1

Type: Stratigraphic well.
License to Prospect: 210H.
Latitude and Longitude: 18° 10′ 56″S, 123° 29′ 06″E.
Elevation: G. L. 209 feet, R. T. 214 feet.
Commenced: 22nd July, 1968.
Completed: 5th August, 1968.
Total depth: 2,504 feet.
Bottomed in: Upper Devonian.
Status: Dry, completed as a water well.

Willara Hill No. 1

Type: Test well.
License to Prospect: 211H.
Latitude and Longitude: 19° 03′ 31″S, 121° 52′ 45″E.
Elevation: G. L. 247 feet, R. T. 252 feet.
Commenced: 10th August, 1968.
Completed: 22nd August, 1968.
Total depth: 2,814 feet.
Bottomed in: Lower Permian.
Status: Dry, plugged and abandoned.

PERMIT TO EXPLORE 152H

Permit to Explore 152H is held by Beach-General Exploration Pty Ltd and is farmed out to Australian Aquitaine Petroleum Pty Ltd. The company drilled one dry test well on the consession during 1968. Details are as follows:

Wilson Cliffs No. 1

Type: Test well.
License to Prospect: 199H.
Latitude and Longitude: 22° 16′ 39″S, 126° 46′ 55″E.
Elevation: G.L. 1,444 feet, K.B. 1,460 feet.
Commenced: 8th June, 1968.
Completed: 28th November, 1968.
Total depth: 12,212 feet.
Bottomed in: Proterozoic.
Status: Dry, plugged and abandoned.

PERMIT TO EXPLORE 193H

Permit to Explore 193H is held by Hawkstone Minerals Ltd and B.P. Petroleum Development Australia Pty Ltd. B.P. drilled a stratigraphic well on the concession during 1968. Details are as follows:

Gun Island No. 1

Type: Stratigraphic well.
License to Prospect: 205H.
Latitude and Longitude: 28° 53′ 30″S, 113° 51′ 27″E.
Elevation: G. L. 10 feet, K. B. 24 feet.
Commenced: 26th June, 1968.
Completed: 12th November, 1968.
Total depth: 12,220 feet.
Bottomed in: Lower Jurassic.
Status: Dry, plugged and abandoned.

PERMIT TO EXPLORE 217H

Permit to Explore 217H is held by West Australian Petroleum Pty Ltd and covers part of the Carnarvon Basin. The company drilled six stratigraphic wells on the concession during 1968, four of them on islands. Details are as follows:

Direction Island No. 1

Type: Stratigraphic well.
License to Prospect: 204H.
Latitude and Longitude: 21° 32′ 03″S, 115° 07′ 42″E.
Elevation: G. L. 15 feet, R. T. 20 feet.
Commenced: 26th April, 1968.
Completed: 7th May, 1968.
Total depth: 2,207 feet.
Bottomed in: Lower Permian.
Status: Dry, plugged and abandoned.

Mangrove Island No. 1.

Type: Stratigraphic well.
License to Prospect: 162H.
Latitude and Longitude: 21° 14′ 22″S, 115° 46′ 04″E.
Elevation: G.L. 15 feet, R.T. 20 feet.
Commenced: 6th June, 1968.
Completed: 14th June, 1968.
Total depth: 938 feet.
Bottomed in: ?Lower Permian.
Status: Minor gas show, plugged and abandoned.

Mary Anne No. 1

Type: Stratigraphic well.
License to Prospect: 202H.
Latitude and Longitude: 21° 17′ 55″S, 115° 30′ 04″E.
Elevation: G.L. 15 feet, R.T. 20 feet.
Commenced: 12th May, 1968.
Completed: 21st May, 1968.
Total depth: 1,750 feet.
Bottomed in: Middle to Lower Triassic.
Status: Dry, plugged and abandoned.

Mulyery No. 1

Type: Stratigraphic well.
License to Prospect: 186H.
Latitude and Longitude: 21° 18′ 26″S, 115° 47′ 48″E.
Elevation: G.L. 15 feet, R.T. 20 feet.
Commenced: 22nd January, 1968.
Completed: 23rd January, 1968.
Total depth: 458 feet.
Bottomed in: Upper Jurassic.
Status: Gas show, plugged and abandoned. Flow test through perforations over interval 406-420 feet flowed gas at 0.04 mmcf/day.

North Sandy Island No. 1

Type: Stratigraphic well.
License to Prospect: 162H.
Latitude and Longitude: 21° 06′ 25″S, 115° 38′ 56″E.
Elevation: G.L. 15 feet, R.T. 20 feet.
Commenced: 23rd May, 1968.
Completed: 3rd June, 1968.
Total depth: 2,000 feet.
Bottomed in: Middle to Lower Triassic.
Status: Minor gas show, plugged and abandoned.

Peedamullah No. 1

Type: Stratigraphic well.
Latitude and Longitude: 21° 24′ 26″S, 115° 37′ 50″E.
Elevation: G.L. 18 feet, R.T. 23 feet.
Commenced: 24th December, 1967.
Completed: 7th January, 1968.
Total depth: 1,077 feet.
Bottomed in: Devonian.
Status: Dry, plugged and abandoned.

PERMIT TO EXPLORE 259H

Permit to Explore 259H is held by West Australian Petroleum Pty Ltd., and is farmed out to Total Exploration Australia Pty Ltd. This company drilled a test well and two stratigraphic wells on this permit during 1968. All were dry and were plugged and abandoned. Details are as follows:

Edgar Range No. 1

Type: Stratigraphic well.
License to Prospect: 213H.
Latitude and Longitude: 18° 45′ 26″S, 123° 35′ 33″E.
Elevation: G.L. 434 feet, K.B. 447 feet.
Commenced: 10th August, 1968.
Completed: 14th September, 1968.
Total depth: 6,457 feet.
Bottomed in: Precambrian.
Status: Dry, plugged and abandoned.

Kemp Field No. 1

Type: Stratigraphic well.
License to Prospect: 216H.
Latitude and Longitude: 20° 19′ 10″S, 123° 27′ 58″E.
Elevation: G.L. 768 feet, K.B. 782 feet.
Commenced: 28th September, 1968.
Completed: 13th October, 1968.
Total depth: 3,875 feet.
Bottomed in: Devonian.
Status: Dry: plugged and abandoned.

McLarty No. 1

Type: Test well.
License to Prospect: 200H.
Latitude and Longitude: 19° 23′45″S, 123° 39′30″E.
Elevation: G.L. 558 feet, K.B. 572 feet.
Commenced: 14th May, 1968.
Completed: 30th July, 1968.
Total depth: 8,500 feet.
Bottomed in: Ordovician.
Status: Dry, plugged and abandoned.

PERMIT TO EXPLORE 260H

Permit to Explore 260H is held by West Australian Petroleum Pty. Ltd. and is farmed out to Marathon Petroleum Australia Ltd. This company commenced one test well on the permit during 1968. Details are as follows:

Remarkable Hill No. 1

Type: Test well.
License to Prospect: 215H.
Latitude and Longitude: 22° 57′ 20″S, 114° 09′ 20″E.
Elevation: G.L. 350 feet, K.B. 364 feet.
Commenced: 15th October, 1968.
Status: Drilling at 7,959 feet on 31st December.

PERMIT TO EXPLORE 261H

Permit to Explore 261H is held by West Australian Petroleum Pty. Ltd. and is farmed out to Union Oil Development Corp. That company drilled one test well, Whicher Range No. 1 on the permit during 1968. Moderate flows of gas were obtained from the Permian sequence, but the well was abandoned as being non-commercial. Details are as follows:

Whicher Range No.1

Type: Test well.
License to Prospect: 198H.
Latitude and Longitude: 30° 50′ 21″S, 115° 22′ 12″E.
Elevation: G.L. 485 feet, K.B. 501 feet.
Commenced: 19th March, 1968.
Completed: 28th August, 1968.
Total depth: 15,226 feet.
Bottomed in: Upper Permian.
Status: Non-commercial gas well, plugged and abandoned. A drill stem test of the interval 13,662½-13,694 feet flowed gas 1.93 mmcf/day on ½-inch choke. Other intervals between 12,958½ and 13,794½ feet flowed gas at lesser rates.

GEOPHYSICAL OPERATIONS

Seismic

During 1968 seismic surveys were conducted in the Perth, Carnarvon, Canning, Bonaparte Gulf, and Eucla Basins. This work was distributed as follows:

Company	Permit	Basin	Party months
Westralian Sands Limited	106H and 253H	Canning	0·8 (land)
West Australian Petroleum Pty Ltd	27H	Perth	1·5 (land)
Do. do. do.	27H and WA-14-P	Perth	3·0 (marine)
Do. do. do.	28H	Carnarvon	1·5 (land)
Do. do. do.	28H and WA-24-P	Carnarvon	3·1 (marine)
Do. do. do.	30H	Canning	2·4 (land)
Do. do. do.	30H	Canning	2 days (marine)
Do. do. do.	217H and WA-23-P	Carnarvon	3·2 (marine)
Do. do. do.	225H and WA-13-P	Perth	1·6 (marine)
Do. do. do.	233H and WA-25-P	Carnarvon	1·1 (marine)
Total Exploration Australia Pty Ltd	WA-20-P	Perth	0·15 (marine)
Australian Aquitaine Pty Ltd	205H	Canning	2·0 (land)
Do. do. do.	152H	Canning	0·66 (land)
Do. do. do.	151H	Canning	1·26 (land)
B.O.C. of Australia Ltd	213H	Canning	3·0 (marine)
Arco Limited	221H	Bonaparte	2·5 (marine)
Union Oil Development Corporation	261H	Perth	4·5 (land)
Canadian Superior Oil (Aust.) Pty Ltd	235H	Carnarvon	½ day (marine)
Marathon Petroleum Australia Ltd	260H	Carnarvon	5·0 (land)

Gravity

Gravity surveys were carried out during the year in the Canning Basin. Details are as follows:

Company	Permit	Basin	Party months
West Australian Petroleum Pty Ltd	30H	Canning	0·5
Australian Aquitaine Petroleum Pty Ltd	205H	Canning	2·0
Do. do. do.	152H	Canning	0·66
Do. do. do.	151H	Canning	1·26

Magneto-Telluric Surveys

A magneto-telluric survey was carried out during the year in the Canning Basin. Details are as follows:

Company	Permit	Basin	Party months
Australian Aquitaine Petroleum Pty Ltd	205H	Canning	1·46
Do. do. do.	152H	Canning	1·3
Do. do. do.	151H	Canning	0·98

GEOLOGICAL OPERATIONS

Field geological studies were carried out by oil exploration companies in the Perth, Canning, and Carnarvon Basins. Details are as follows:

Company	Permit	Basin	Geologist months
West Australian Petroleum Pty Ltd	27H	Perth	0·5
Do. do. do.	30H	Canning	4·0
Australian Aquitaine Petroleum Pty Ltd	205, 152, and 151H	Canning	1·5
B.O.C. of Australia Limited	213H	Canning	21·0
Marathon Petroleum Australia Pty Ltd	260H	Carnarvon	3·0

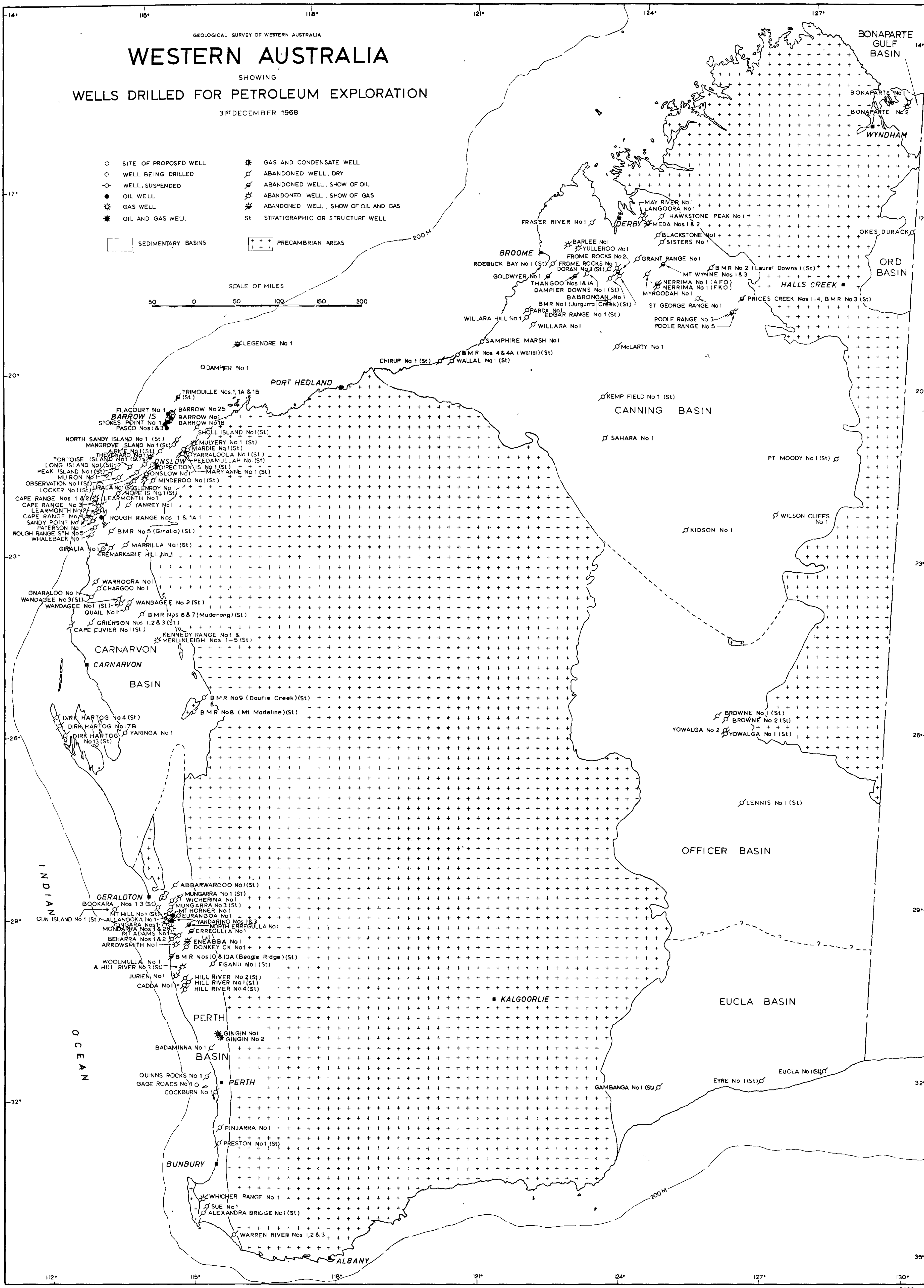

PLATE 9

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PLATE 10

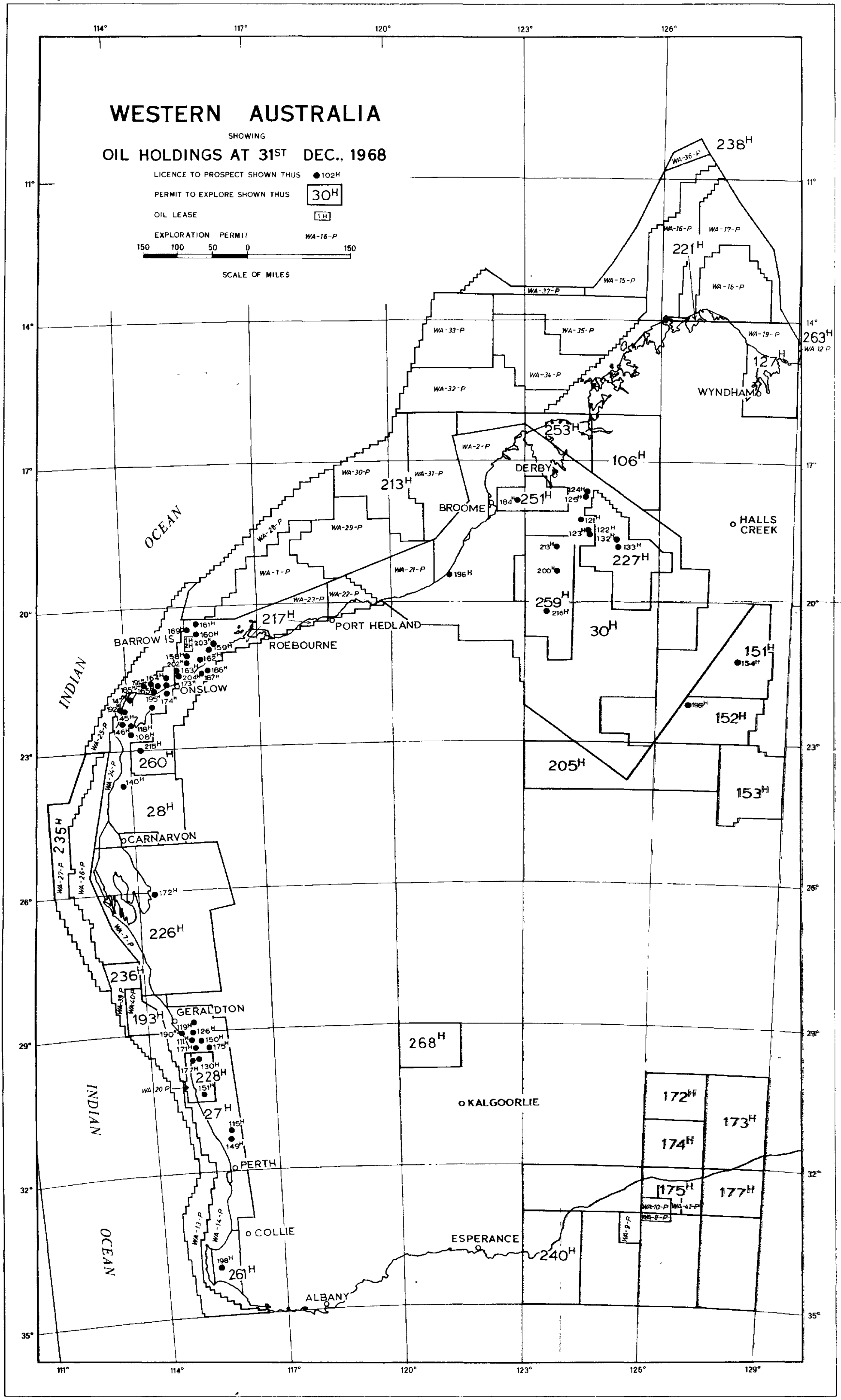

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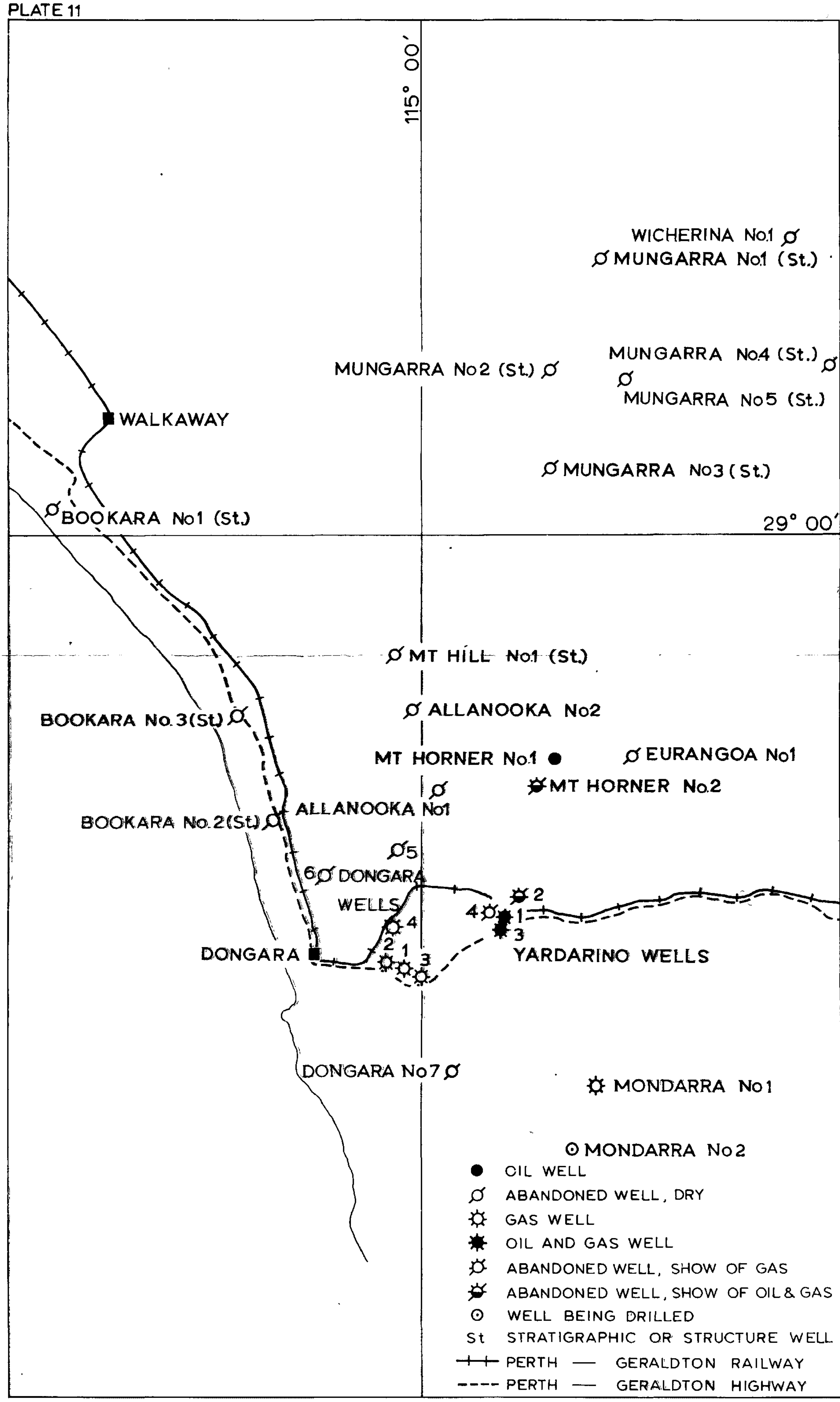
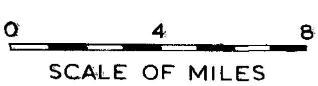
PLATE 11



DONGARA AREA

SHOWING WELLS DRILLED FOR PETROLEUM



PETROLEUM PRODUCTION IN WESTERN AUSTRALIA IN 1968

by A. H. Pippet

Barrow Island is the only producing field in the State at present, although the Dongara and Mondarra fields show promise for eventual economic development.

Development of the Barrow Island Field continued during the year with the drilling of a further 52 producing wells mainly on the primary 80-acre-spacing scheme. The positions of all wells drilled to the end of 1968 are shown on Plate 12.

The pilot water-injection tests initiated in 1967 indicated that favourable injection rates could be obtained in the Windalia reservoir; as a result the company announced that it was proceeding with a field-wide water-flood project which was expected to increase the recoverable reserves to approximately 200 million barrels of oil. By the end of the year 45 water-injection and 5 water source wells had been drilled. In addition to the development wells two 'new-pool wildcats' (Stokes Point No. 1 and Flacourt No. 1) and one 'outpost' (C-52) were drilled with some degree of success. Stokes Point No. 1 (Loc. C-65) was drilled on a possible structure southeast of the main Barrow Island fault. The Jurassic proved non-productive and the well was completed in the Windalia reservoir as an oil and gas well. An 'outpost' well C-52, drilled in a downdip position as a follow-up to Stokes Point No. 1 proved to be water productive and was abandoned. However, on the northeast flank Flacourt No. 1 (Loc. S-27) was completed as a small oil producer and indicated that where trapping conditions are favourable, small accumulations of oil are present in the Windalia beneath the level of the oil-water contact in the main pool.

In addition, sands in the Muderong Formation have been found to be oil productive in the 'F' area, where this reservoir is now being developed.

Oil production rose from 28,700 barrels per day in December 1967 to 30,000 barrels per day in May 1968, at which level production was maintained throughout the remainder of the year. It is anticipated that by the end of 1969 the field production will be of the order of 45,000 barrels per day.

The total footage of holes drilled on Barrow Island during the year amounted to 270,951 feet.

Production statistics for the year are summarized in the following tables.

OIL AND GAS PRODUCTION 1968

Reservoir	Production for year 1968			Cumulative production		
	Oil (bbls)	Water (bbls)	Gas (Mcf)	Oil (bbls)	Water (bbls)	Gas (Mcf)
Windalia	10,479,076	170,969	8,000,976	15,122,857	186,691	10,976,718
Muderong	20,811	204	9,325	20,811	204	9,325
Jurassic 6200'	529	690	12,851	9,423	4,770	65,177
Jurassic 6600'	45,933	43,352	167,228	106,098	47,620	341,488
Jurassic 6700'	236,332	20,817	466,424	439,763	39,647	715,083
Total field	10,782,681	236,032	8,656,804	15,698,952	278,932	12,107,791
Windalia	Water injected, 1,975,967 bbls			Cumulative water injected, 2,044,319 bbls		

OIL AND GAS DISPOSAL 1968

	Oil (bbls)	Gas (Mcf)
Total production	10,782,681	8,656,804
Used in drilling	463	....
Field fuel	4,695	92,922
Gas flared	....	8,563,882
Percentage field utilization	·0043	1·07
Percentage gas flared	....	98·93
Oil shipments	10,641,703	....

The following table summarizes the wells drilled on Barrow Island (Petroleum Lease 1H) during 1968.

WELLS DRILLED ON BARROW ISLAND DURING 1968

Well	Elevation		Total depth	Com-menced	Com-pleted	Ob-jective*
	Rotary table (feet)	First flange (feet)	(feet)			
A 17	108	98	2580	15/5/68	20/5/68	WI
A 27	86	75	2550	14/6/68	18/6/68	P
A 28	88	77	2540	5/5/68	8/5/68	WI
A 38	154	144	2517 (577)	30/12/67	2/1/68	P
A 47	45	35	2540	2/6/68	7/6/68	WI
B 11	73	62	2487	1/4/68	5/4/68	WI
B 13	79	69	2370	27/4/68	29/4/68	WI
B 22	52	42	2457	5/4/68	10/4/68	WI
B 24	54	43	2320	29/4/68	4/5/68	WI
B 31	48	38	2457	14/4/68	19/4/68	WI
B 33	49	39	2336	20/4/68	23/4/68	WI
B 36	52	41	3613	5/1/68	11/1/68	P
B 41	47	37	2456	23/3/68	27/3/68	P
B 43	46	35	3488	2/2/68	9/2/68	P (Abx)
E 25	85	74	2564	11/1/68	16/1/68	P
F 11	163	153	2380	23/12/68	27/12/68	WI
F 15	192	182	2343	27/12/68	30/12/68	WI
F 17	159	148	482	31/12/68	Drilling	WI
F 22	134	123	2972	11/12/68	17/12/68	P (M)
F 31	173	162	2356	30/7/68	1/8/68	WI
F 33	135	125	2269	26/7/68	29/7/68	WI
F 35	114	103	148	31/12/68	Drilling	WI
F 37	114	104	2284	28/12/68	30/12/68	WI
F 42	127	116	2970	14/11/68	22/11/68	P (M)
F 51	146	135	2915	{11/5/68 29/6/68	16/5/68 10/7/68}	WI
F 53	116	106	2268	22/7/68	26/7/68	WI
F 62	113	103	2246	17/8/68	23/8/68	P (M)
G 11	87	77	2461	3/12/68	5/12/68	WI
G 13	140	130	2461	11/12/68	14/12/68	WI
G 15	147	137	2447	30/11/68	3/12/68	WI
G 17	185	175	2447	20/11/68	24/11/68	WI
G 31	124	113	2510	8/5/68	11/5/68	WI
G 33	154	143	2480	25/6/68	28/6/68	WI
G 35	123	113	2389	16/7/68	18/7/68	WI
G 37	177	167	2364	14/8/68	17/8/68	WI
G 51	131	121	2490	14/11/68	18/11/68	WI
G 53	157	147	2449	10/7/68	13/7/68	WI
G 55	149	139	2358	13/7/68	15/7/68	WI
G 71	109	99	2517	23/4/68	26/4/68	WI
G 73	113	103	2401	20/4/68	24/4/68	WI
G 75	118	107	2401	17/4/68	20/4/68	WI
G 77	104	94	2312	13/4/68	17/4/68	WI
G 82	98	88	2461	25/4/68	27/4/68	WI
G 86	93	83	2311	10/4/68	13/4/68	WI
H 17	92	81	2610	26/11/68	30/11/68	WI
H 37	135	125	2610	23/11/68	26/11/68	WI
H 57	89	78	2550	19/11/68	22/11/68	WI
H 77	101	91	2610	3/5/68	9/5/68	P
H 87	122	111	2600	20/6/68	25/6/68	WI
H 88	124	113	2580	27/4/68	3/5/68	WI
K 12	151	141	2576	23/2/68	28/2/68	P
K 14	192	182	2547	16/2/68	22/2/68	P
K 16	179	168	2547	28/1/68	1/2/68	P
K 21	114	103	2547	22/3/68	25/3/68	P
K 23	152	141	2515	4/2/68	12/2/68	P
K 32	172	162	2576	28/2/68	2/3/68	P
K 34	164	153	2518	15/3/68	18/3/68	P
K 36	192	181	2517	5/3/68	8/3/68	P
K 41	160	149	2547	11/3/68	14/3/68	P
K 43	183	173	2547	8/3/68	11/3/68	P
K 54	137	126	2487	13/2/68	16/2/68	P
K 56	142	131	2457 325)	30/12/67	4/1/68	P

Well	Elevation		Total depth (feet)	Commenced	Completed	Objective*
	Rotary table (feet)	First flange (feet)				
K 58	170	159	2456	9/3/68	12/3/68	P
K 61	104	93	2576	2/3/68	6/3/68	P
K 63	145	134	2488	22/1/68	26/1/68	P
K 65	167	156	2456	15/3/68	18/3/68	P
K 67	187	176	2456	12/3/68	15/3/68	P
K 71	122	112	2551	30/11/68	3/12/68	WI
K 73	165	155	2461	6/12/68	8/12/68	WI
K 75	141	130	2431	8/12/68	11/12/68	WI
K 77	196	186	2448	25/11/68	28/11/68	WI
L 12	208	197	2518	19/1/68	22/1/68	P
L 21	199	188	2517	3/1/68	5/1/68	P
L 23	198	188	2517	20/2/68	23/2/68	P
L 32	198	188	2436	28/3/68	2/4/68	P
L 36	206	196	2456	9/2/68	13/2/68	P
L 38	158	148	2487	16/1/68	19/1/68	P
L 41	182	171	2480	19/1/68	27/1/68	P
L 43	210	200	2487	31/1/68	4/2/68	P
L 53	194	184	2407	14/12/68	17/12/68	WI
L 71	170	160	2370	17/12/68	20/12/68	WI
L 73	169	152	2350	20/12/68	23/12/68	WI
M 27	128	118	2569	16/5/68	19/5/68	P
M 47	105	95	2537	18/3/68	23/3/68	P
P 81	180	169	2547	13/1/68	16/1/68	P
P 87	123	113	2547	25/3/68	31/3/68	P
Q 14	193	183	2570	18/7/68	21/7/68	P
Q 32	116	105	2547	28/3/68	31/3/68	P
Q 41	180	169	2576	18/3/68	21/3/68	P
Q 61	120	110	2518	7/1/68	10/1/68	P
Q 74	166	155	2487	16/1/68	18/1/68	P
Q 78	169	159	2516	13/2/68	16/2/68	P
Q 83	173	163	2517	16/2/68	20/2/68	P
R 47	92	81	2491	12/5/68	15/5/68	P
R 58	186	175	2547	29/2/68	4/3/68	P
R 67	118	108	2491	9/5/68	12/5/68	P
R 85	147	137	2518	4/1/68	7/1/68	P
T 87	159	149	2576	10/1/68	13/1/68	P
WSW 1 A, B 13	93	83	3675	19/5/68	25/5/68	WSW
WSW 1 B, G 74	102	91	3700	26/5/68	2/6/68	WSW
WSW 2 A, G33	114	103	3600	2/8/68	9/8/68	WSW
WSW 3 A, F 15	165	155	3539	4/12/68	11/12/68	WSW
WSW 4 A M 54	144	134	4029	18/12/68	26/12/68	WSW

Total development drilling, 1968 : 257,181 feet.

Datum adopted for Barrow Island wells is 18·54 feet above mean sea level or 23·44 feet above Indian spring low water mark.

* P = Windalia producer.
P (M) = Muderong producer.
WI = Windalia water injector.
WSW = water source well.
(Abx) = Abandoned.

NEW POOL WILDCAT WELLS (2)

Stokes Point No. 1 (Location C-65)

Latitude and longitude: 20° 52′ 55″S, 115° 22′ 55″E.

Elevation: G.L. 59 feet, R.T. 73 feet.

Commenced: 9th May, 1968.

Completed: 16th June 1968.

Total depth: 8,150 feet.

Bottomed in: Upper Jurassic.

Status: Oil and gas well. Completed in zones between 2,602 to 2,630 feet.

Flacourt No. 1 (Location S-27)

Latitude and longitude: 20° 44′ 44″S, 115° 22′ 40″E.

Elevation: F.F. 165 feet, R.T. 175 feet.

Commenced: 8th June, 1968.

Completed: 13th June, 1968.

Total depth: 2,680 feet.

Bottomed in: Lower Cretaceous.

Status: Oil well, completed in zones between 2,396 to 2,425 feet.

OUTPOST WELLS (1)

Location C-52

Elevation: F.F. 43 feet, R.T. 54 feet.

Commenced: 9th August, 1968.

Completed: 14th August, 1968.

Total depth: 2,940 feet.

Bottomed in: Lower Cretaceous.

Status: Plugged and abandoned.

THE ORIGIN OF SMALL CAVITIES IN THE LIMESTONE OF THE BUNDA PLATEAU, EUCLA BASIN

by D. C. Lowry

ABSTRACT

The limestone of the Bunda Plateau contains several varieties of small cavities between the surface and the water table some 200 to 400 feet below. Some near-surface cavities have previously been attributed to phreatic solution below a late Cainozoic water table which stood within a few feet of the present surface, but this article shows that some of the cavities were formed by tree roots and others by surface weathering. Cavities of undoubted phreatic or epi-phreatic origin are recognized only up to about 250 feet above the present water table, and a late Cainozoic elevation of sea level by that amount is inferred.

INTRODUCTION

The Bunda Plateau covers some 50,000 square miles of Western Australia. Its southern part is underlain by Miocene limestones of the Eucla Group, and the plateau slopes southwards from an altitude of 500 to 650 feet near the Trans Australian Railway to about 200 to 350 feet at the scarp that forms its southern boundary (Figure 7). The low rainfall (7 to 12 inchest annually) and the generally high permeability of the limestone means that most of the plateau is underlain by a water table of low relief. Large caves are relatively rare, but in most areas the limestone is riddled with small cavities at various levels above the water table. Jennings (1958, 1961) referred to some of the cavities as 'solution tubes' and interpreted them as having formed below a water table which stood within a few feet of the present surface of the plateau. Although I formerly agreed with this suggestion (Lowry, 1964), I have since examined most quarries and large caves in the Western Australian part of the plateau, and now believe that Jennings has misinterpreted the origin of some of the cavities.

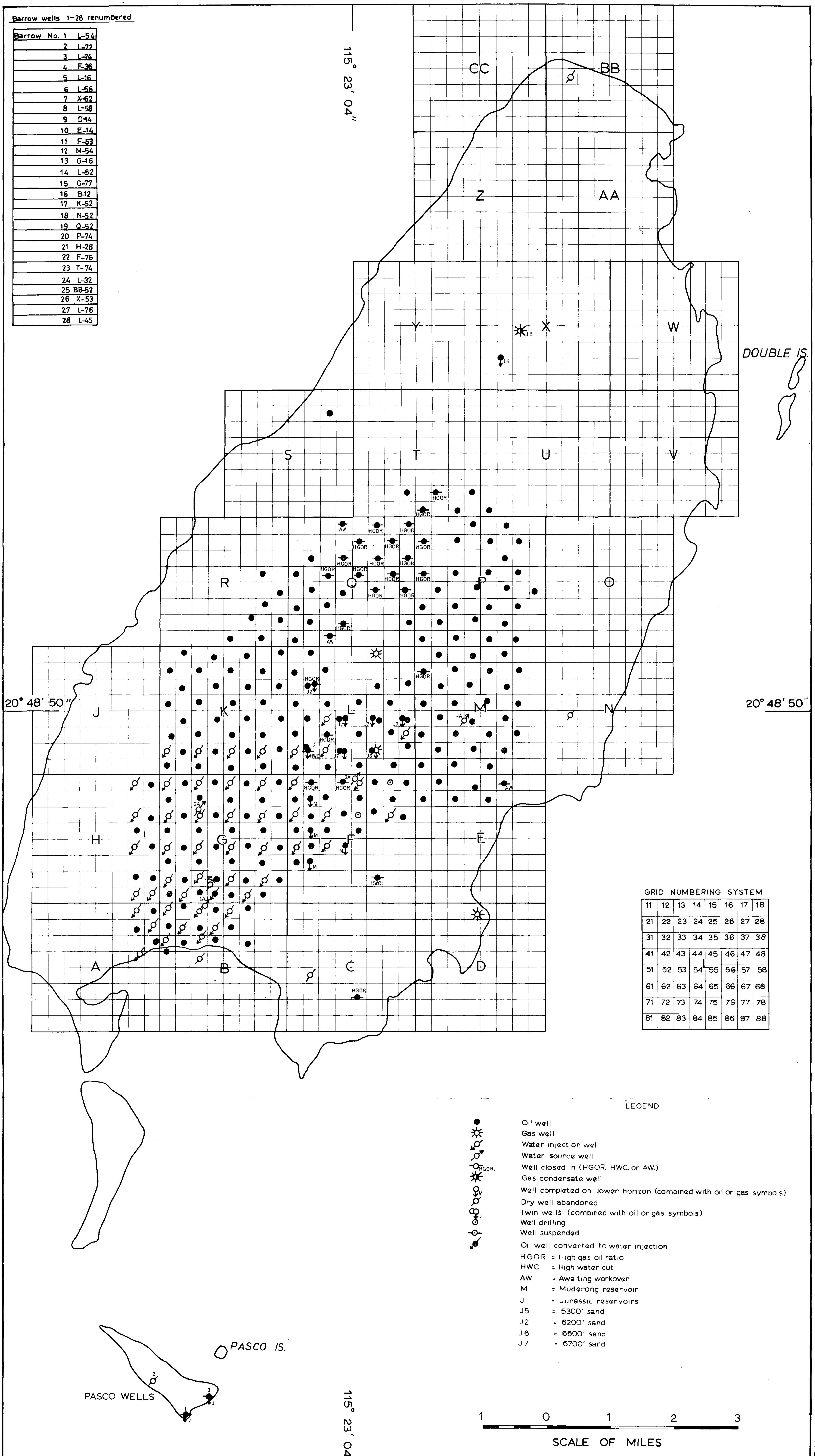
In the last 25 years, much of the speleological literature on the origin and development of limestone caves has been devoted to distinguishing between cave formation in the vadose, epi-phreatic. and phreatic zones (above the water table, just below the water table, and far below it.) The distinction has usually been made by identifying the diagnostic morphological features described in the classic paper by Bretz (1942). This article shows that such identification is not always easy.

VARIETIES OF CAVITIES

There is a great diversity of small cavities in the limestone, and the following classification is a tentative one. There appear to be gradations between the various types of cavity and detailed study would probably result in an even more complex classification.

Anastomosing tubes developed on fracture surfaces

The tubes are mostly developed along fractures in near-surface limestone, and are exposed as half-tubes by collapse of walls of dolines, cliffs and quarries (see Plate 13A, and Jennings 1967a Figure 2-9). The tubes anastomose freely in all directions and occasionally penetrate the limestone between fracture surfaces. The diameter



BARROW ISLAND AREA
WINDALIA RESERVOIR

PLATE 12

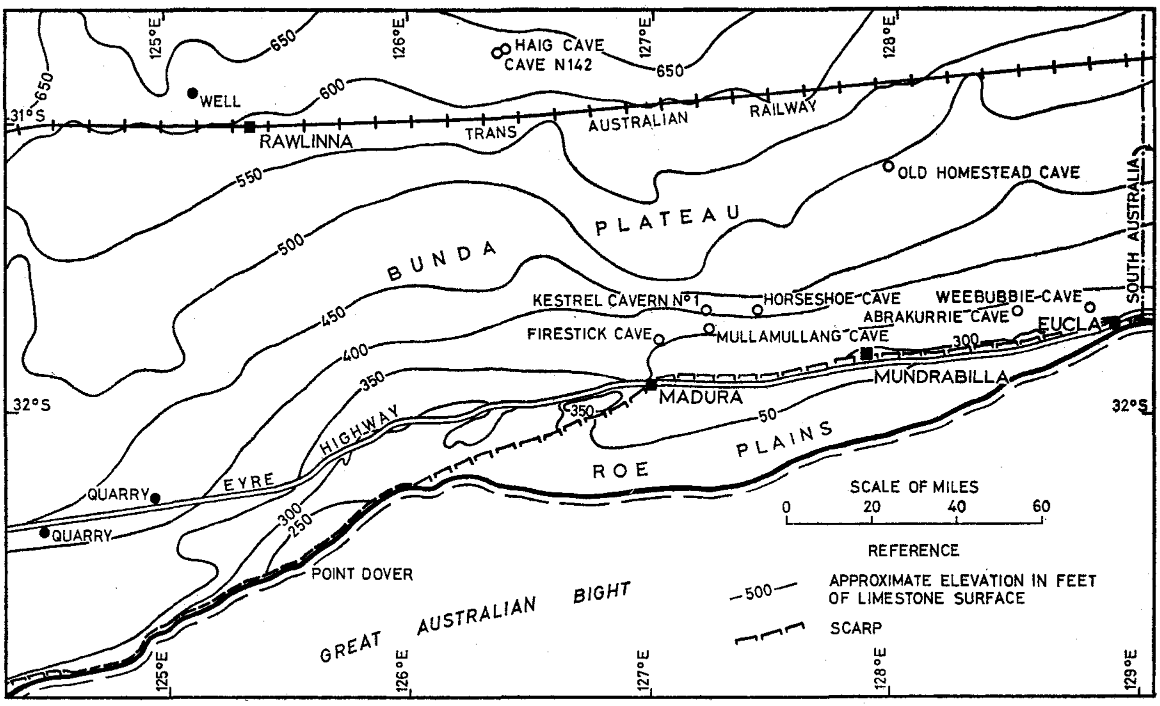


Figure 7. Sketch plan of part of the Eucla Basin. Contours show elevation of surface of Tertiary limestone; coastal dunes are omitted.

ranges from about 10 centimeters down to a few milimeters, and each tube has a remarkably constant diameter. They are commonest in the interval from 5 to 50 feet below the surface. Jennings (1963 p. 50) described them as "anastomosing networks of small half-tubes exposed on bedding and joint-planes" and favoured a phreatic origin because of their apparent similarity to phreatic features described by Bretz (1942) and Glennie (1954). Jennings presumably intended a comparison with Bretz's "bedding-plane anastomosis" and "joint-plane anastomosis." However, they differ in the following ways:

(1) Although the tubes are concentrated along fracture planes, they also penetrate the solid limestone between fractures, whereas tubes of a bedding-plane anastomosis are restricted to the particular bedding plane.

(2) They are remarkably circular in cross section whereas tubes of bedding-plane anastomoses are bulbous (Bretz, 1942) or trapezoidal (Ewers, 1966).

(3) When the tubes along fractures developed, they widened symmetrically on both sides of the fracture, whereas the tubes of bedding-plane anastomoses only enlarged upwards into the overlying bed.

(4) Tubes exposed on any particular surface of Eucla Group limestone have a great range in size, whereas bedding-plane anastomoses have tubes of about equal size (Ewers, 1966).

Although Bretz (1942) introduced the term "joint-plane anastomosis", he found the feature to be so rare that he did not describe it in sufficent detail to allow determination of the extent of its similarity to the tubes on fractures in Eucla Group limestone. Jennings (1967b) also referred to "spongework", but Bretz (1942) described spongework as having "amazingly intricate perforated partitions and remnants of partitions" and as ranging in size up to cave passages. The spongework of Bretz therefore has a much higher proportion of cavity to limestone that the tubes described here, although the comparison might be valid for features described later under 'Irregular cavities'. There are sufficient differences therefore between tubes in the limestones of the Eucla Group and the phreatic features of Bretz (1942) to suggest that they have different origins.

The anastomoses in the fractures of the Eucla Group limestones are most likely to have been caused by tree roots. Evidence for this is as follows:

(1) Tree roots or bundles of roots can occasionally be seen occupying tubes; for example at quarries on the Eyre Highway near the 173 and 206 mile pegs east of Norseman, and in road cuttings at Madura, Mundrabilla, and Eucla (Plate 13A).

(2) In some places close to the surface of the plateau, tubes following vertical fractures tend to be vertical (see Plate 13B).

(3) The tubes are similar to other tubes believed to have been formed by tree roots. Jennings's (1967a) Figure 2-9 strongly resembles Plate 4 of Wall and Wilford (1966).

(4) Illustrations of bedding-plane anastomoses show that the tubes branch in a series of 'Y' junctions, whereas tubes in Eucla Group limestones sometimes cross over each other in an 'X' junction.

(5) Many tubes are filled with clay, and others with clay that has partly or completely lithified.

The range in degree of lithification suggests a range of ages, and therefore is more in keeping with the tree-root hypothesis.

(6) Tree roots are capable of penetrating considerable depths below the plateau. Quarries and road cuttings show they penetrate at least 10 feet, but the most striking example is Mullamullang Cave, where rotted wood in the cave is thought to have come from the roots of *Acacia* sp. growing more than 150 feet above (Hamilton-Smith *in* Hill 1966).

Where a root or bundle of roots is observed occupying a tube freshly exposed by quarrying, they do not fill the tube, but are surrounded by clay. The tubes probably form by corrosion by root exudates (Wall and Wilford, 1966) and vadose water seeping through the clay. If the seepage is by capillarity, the tubes could develop features which are usually associated with phreatic flow such as anastomoses and irregular gradients.

Surface pitting

The exposed limestone surface in many dolines shows an abundance of circular openings about 1 to 6 inches across. The openings give the impression of being part of a maze of tubes penetrating the limestone, but in fact they are blind and do not penetrate more than a few inches. Plate 13c shows roof surface which developed pitting and then partly collapsed. The fresh surfaces on the right of the photograph do not show the holes that would be expected if the openings on the left of the photograph represented the ends of a maze of tubes. Figure 2-10 of Jennings (1967a) possibly illustrates pits of this type rather than solution tubes. The origin of the pits is uncertain, but the fact that they seem concentrated on overhanging and other dry surfaces, and have an apparent association with films of halite, suggests that some sort of exudation mechanism may be in operation. In any case, the pits are younger than the doline walls, and a phreatic origin is improbable.

Irregular cavities with smoothly curving walls

These cavities, which are usually filled with red clay, are distinguished from the root tubes by having smoothly curving walls with little constancy of diameter. They are also somewhat larger, ranging up to 20 inches in diameter, and seem to have a greater proportion of cavity to limestone. The tubes are not concentrated on fracture planes, although they do seem to be concentrated at disconformities. The zone in which they develop varies. In Haig Cave they extend from 25 to 140 feet below the surface and are particularly concentrated at the disconformity between the Nullarbor Limestone and the Wilson Bluff Limestone 94 feet below the surface. In Old Homestead Cave there are irregular clay-filled cavities at about 50 feet below the surface and in Abrakurrie Cave there is a zone at about 90 feet. In a few instances the tubes lie quite close to the surface; in an old well (lat. 30° 56'S, long. 125° 04'E) there is abundance of irregular clay-filled tubes from 20 to 110 feet below the surface, while in cave N142, they occur only 10 feet below the surface. The clay fillings show no signs of bedding.

The cavities are possibly the type that Jennings (1967b) referred to as spongework, and it is possible that they formed by phreatic solution. However, a vadose origin is also conceivable. Water seeping through clay-filled tubes could perhaps enlarge them into a three-dimensional maze that would resemble the work of slowly moving phreatic water.

Horizontal flat-bottomed cavities

These cavities range from a few inches to about 2 feet in width, and are up to about 1 foot high. They have flat bottoms and irregular tops, and are usually filled with horizontally-layered calcite. Usually they occur in a flat zone some distance below the surface of the plateau. At Mullamullang Cave, for example, there is a zone of these cavities about 60 feet below the surface (about 330 feet above the water table), but on the cliffs near Point Dover, there is a zone only 8 feet below the surface (about 200 to 250 feet above sea level). The horizontality of the cavities suggests that their formation was controlled either by a water table, or by horizontal bedding. Even if the cavities do represent former water table levels, it was possibly only a local effect. Small perched bodies of water occur beneath 'dongas' (solution dolines) in the Rawlinna area at the present time and since the flat-bottomed cavities occur mainly in indurated limestone of low permeability, it is conceivable that perched bodies of water could have developed in other parts of the plateau in the past.

Horizontal rectilinear cave passages

Several of the deeper caves of the Bunda Plateau intersect horizontal rectilinear cave passages 2 to 10 feet in diameter. The passages have smoothly curved walls and approximately circular cross sections. Their direction is controlled by jointing; in places they form networks in a horizontal plane and in others they form at different levels on the same joint. In Mullamullang Cave (Hill, 1960) the Ezam Extension has two levels 290 and 300 feet below the plateau (100 and 90 feet respectively above the present water table), while the Easter Extension has three levels about 20, 40, and 60 feet above the water table. Firestick Cave and Old Homestead Cave have passages 220 feet below the plateau, and Kestrel Cavern No. 1 has what is possibly the shallowest set of passages 160 feet below the plateau (about 250 feet above the present water table). Several of the passages are partly filled with well-bedded red clay.

The networks and approximately circular cross sections indicate a phreatic or epi-phreatic origin (Bretz, 1942), and the horizontality indicates control either by bedding or by the water table. The Abrakurrie Limestone in which most of the passages are developed is porous and weakly bedded, so the cave passages probably mark the approximate levels of former water tables.

DISCUSSION

The only cavities that can confidently be attributed to phreatic solution are the joint-controlled passages described above. These imply that the water table stood at various levels from 10 to about 250 feet above its present level. This elevation could have been caused either by an increase in intake of vadose water (because of a colder or wetter climate), or an elevation in sea level. Hill (1966) calculated that the water table at Mullamullang Cave is 20 feet above sea level, but my measurements indicate it is even lower, probably less than 5 feet. The cave lies 42 miles from the sea, and this exceptionally low water table gradient is probably due to the very high permeability of the limestone. Even if the climate changed sufficiently to double the intake of vadose water and so approximately doubled the water table gradient, the water table would still be only about 10 feet above sea level at Mullamullang Cave and the adjacent Kestrel Cavern No. 1. Thus any major change in the water table level in the vicinity of these caves was probably due to changes in sea level, and the passages in Kestrel Cavern No. 1 therefore indicate that the sea once stood about 250 feet above its present level for a period long enough for the cave passages to develop.

The high sea level occurred at some time between emergence of the plateau in the Miocene, and deposition of Pleistocene marine shell beds 100 feet above sea level on the Roe Plains. The sea level possibly marks the early Pleistocene 'Sicilian' high sea level recognized by some writers, but it could also have occurred at some time in the Pliocene or even Miocene.

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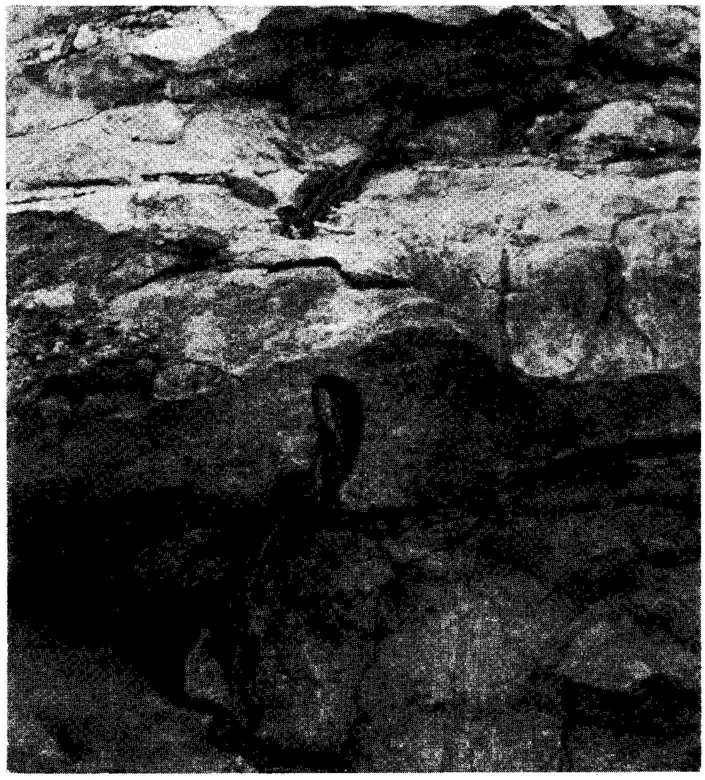
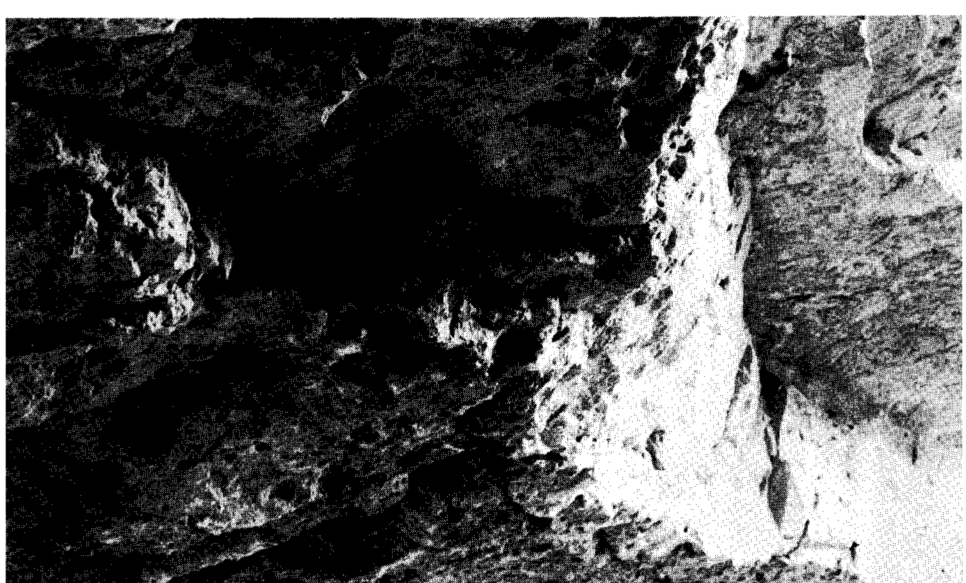


A.—Tube occupied by a bundle of tree roots, Eucla Pass. Note the anastomosis of fine tubes on the left.
FN 1362.

B.—Half tubes exposed at Kuthala Pass, 40 miles west of Eucla. Most of the tubes follow the direction of greatest slope of the fracture surface.
FN 1363.



C.—Pitted roof of Horseshoe Cave doline. The absence of cavities in the freshly exposed limestone surface on the left indicates that the cavities on the right are due to pitting and are not the ends of anastomosing tubes.
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PRECAMBRIAN TECTONIC UNITS OF WESTERN AUSTRALIA

by J. L. Daniels and R. C. Horwitz

ABSTRACT

A map is presented depicting the localities and names of broad tectonic units of the Precambrian of Western Australia.

The geology of Western Australia is conveniently divisible into a number of regional units and, for ease of reference, these should be consistently named. The names chosen should be geographical and pertaining to a tectonic unit, but not so rigid as to preclude any further subdivision. This is largely established for the Phanerozoic sedimentary basins, as outlined on a map by Playford and Low (1968). In the Precambrian however, there is less consistency in the nomenclature of the tectonic units.

This paper and the map (Plate 14) present broad tectonic units with names for the Precambrian of Western Australia. For a number of these units several names have been published and it is thought necessary to tabulate these for clarification with some references. The names that we have chosen are, in most cases, selected from literature; for a few units, a new name is introduced. The boundaries on the map are as compiled by Horwitz (1966). A review of all the geochronology of the Precambrian upon which some of these boundaries are based is given in Compston and Arriens (1968): a map with a generalization of these results appeared in Peers and Trendall (1968).

It is not our intention to define the real, as distinct from the erosional limit of each unit as, in some cases, data is inadequate and not likely to be available for some time.

The Precambrian of Western Australia is subdivided into the major units listed in the accompanying table.

Name	Other names, approximate analogies, comments	Age of predominant rocks	Approximate size in sq. miles
Yilgarn Block (Prider, 1965)	Yilgarn Nucleus (Hills, 1965)	Archaean	240,000
Pilbara Block (Prider, 1965)	Pilbara Nucleus (Hills, 1965)	Archaean	20,000
Albany - Fraser Province	Albany-Esperance Block (Prider, 1965) Frazer Range (Compston and Arriens, 1968) is part of this belt	Archaean rocks. Middle Proterozoic granites and metamorphism	25,000
Gascoyne Block	....	Archaean and Lower Proterozoic rocks and Proterozoic metamorphism	25,000
Paterson Province	....	Of unknown age	12,000
Northampton Block	Northampton District (Clarke, 1931) Greenough Block (Fairbridge, 1951) Northampton Block (Hills, 1965)	Proterozoic metamorphism	14,000
Naturaliste Block	Leeuwin Block (Prider, 1965) Leeuwin - Naturaliste Block (Peers and Trendall, 1968)	Upper Proterozoic metamorphism	600
Hamersley Basin (Trendall and Blockley, in press)	Mt. Bruce Supergroup (Peers and Trendall, 1968) Part of Median Belt (of Prider, 1965, and Hills, 1965) Nullagine Basin (Daniels, 1966)	Lower Proterozoic sedimentary rocks	50,000
Bangemall Basin	Part of Median Belt (of Prider, 1965, and Hills, 1965)	Lower Proterozoic	50,000
Musgrave Block (Wilson, 1953)	Pitjentara Shield (Chewings, 1935) Pitjandjara Archaean Block (Johnson, 1963) Musgrave - Warburton Block (Wilson, 1954) Musgrave Mann Complex (Brown, Campbell and Crook, 1968)	Middle Proterozoic	18,000
Arunta Block (Chewings, 1935)	Arunta Complex (Mawson and Madigan, 1930)	Includes Proterozoic	In Western Australia 4,000
Halls Creek Province	Includes Halls Creek, Mobile Zone (Harms, 1965), and	Archaean Rocks and Lower Proterozoic igneous rocks	12,000
	King Leopold Mobile Zone (Harms, 1965)	Of unknown age	4,000
Kimberley Basin	Kimberley Block (Noakes, 1953)	Lower Proterozoic	56,000
Lake Mackay Basin	....	Middle and Upper Proterozoic	11,000
Victoria River Basin	Extension in Western Australia of the Victoria River Basin (of Aust. B.M.R., 1962)	Middle and Upper Proterozoic	In Western Australia 5,800
Rawlinson Basin	Extension into Western Australian Precambrian margin of Amadeus Trough (Amadeus Sunkland, Chewings, 1935)	Middle and Upper Proterozoic	6,000

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SAND RIDGE DISTRIBUTION IN THE GIBSON AND GREAT VICTORIA DESERTS OF WESTERN AUSTRALIA

by J. L. Daniels

ABSTRACT

The sand ridge pattern at the junction of the Gibson and Great Victorian Deserts results from a number of factors including: interference of the different wind patterns in the two deserts in a zone straddling the 26° parallel; modification by hills and ranges; and a temporary shift to the north or south of the whole wind pattern.

Sand ridges approximately 10 feet to 60 feet high and up to several tens of miles long are the main character of the Gibson and Great Victoria Deserts of Western Australia. Their general distribution and the causal wind system in both of these deserts has been studied by King (1960). A more detailed study of the orientation and frequency of the sand ridges in the Gibson Desert was undertaken by Veevers and Wells (1961).

King (1960) showed that in the Great Victoria Desert an easterly trend exists. This trend persists into South Australia where it gradually swings to the north and thence into a west-northwesterly or northwesterly trend across the Gibson Desert. The two different main trends of sand ridges in the Gibson and Great Victoria Deserts are therefore related by their physical continuation through South Australia and Northern Territory.

It is the purpose of this contribution mainly to present a more detailed plan of the sand ridge pattern in parts of the Gibson and Great Victoria Deserts and to record and interpret the pattern in the east-west zone straddling the 26° parallel at the junction of the two deserts (Plate 15).

This east-west zone is characterised by a complex pattern which is interpreted as having arisen in a number of ways:

(a) By the production of a number of large eddies in the contact zone of the two wind directions.

(b) By modification of the causal wind direction by hills and ranges. This is especially noticeable between Warburton Mission and the Western Australian border.

(c) By slight north or south shift of the whole wind pattern which apparently allowed some dunes to come under the influence, at different times, of winds from approximately opposing directions. This appears to have produced small areas of crossing dunes and also dunes with conflicting 'Y' intersections.

A minor feature of the dune pattern, indicated on the summarized diagram (Fig. 8) is a number of northeast and northwest-trending narrow zones. Some may extend for a minimum of 400 miles and cross both the Gibson and Great Victoria Deserts. They lie at approximately 45° to the causal wind direction for the regional sand ridge pattern. The writer cannot at present suggest any satisfactory explanation for these features.

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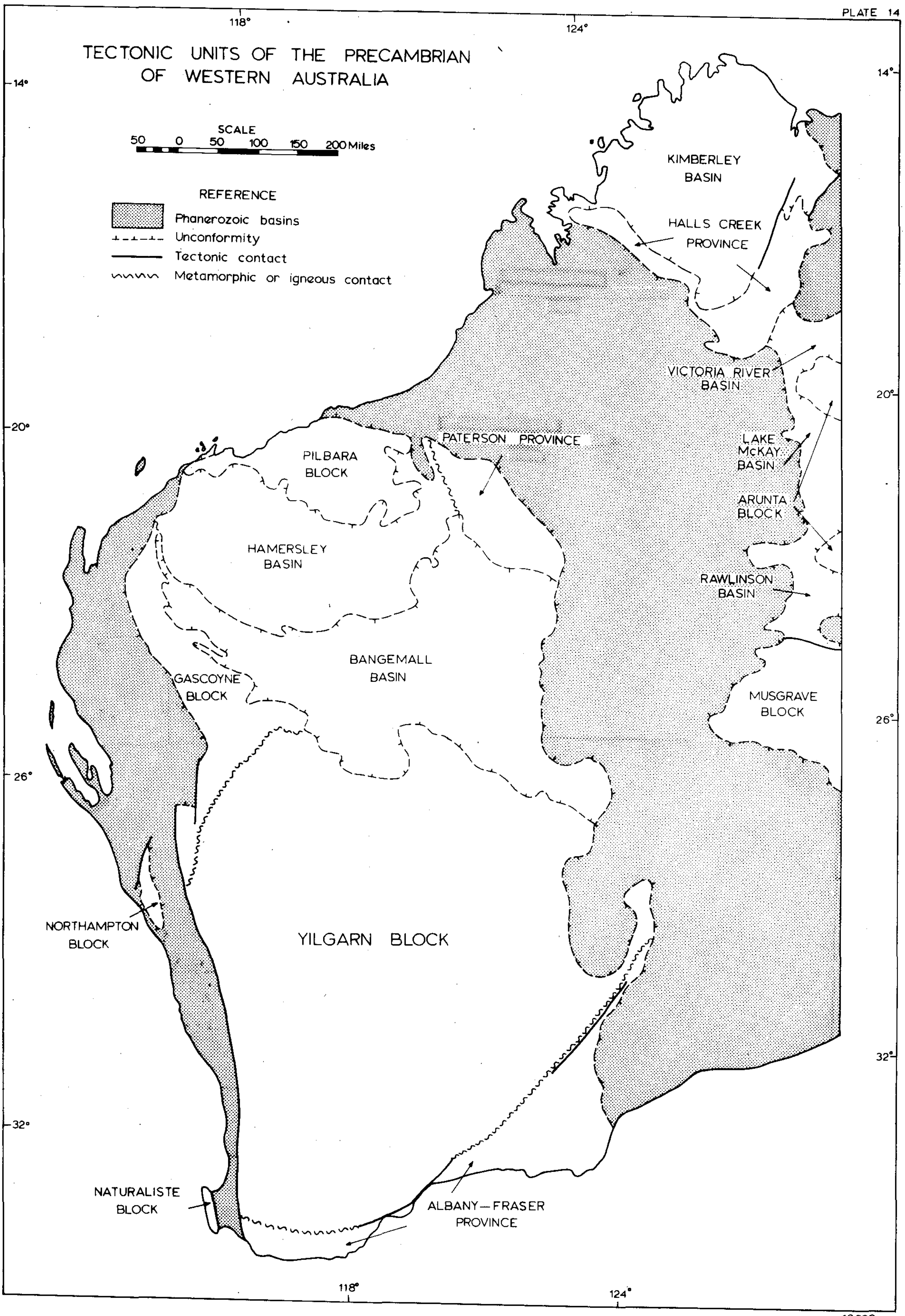
TECTONIC UNITS OF THE PRECAMBRIAN OF WESTERN AUSTRALIA
SCALE
50 0 50 100 150 200 Miles
REFERENCE
Phanerozoic basins
Unconformity
Tectonic contact
Metamorphic or igneous contact
118°
124°
14°
20°
26°
32°
KIMBERLEY BASIN
HALLS CREEK PROVINCE
VICTORIA RIVER BASIN
PATERSON PROVINCE
PILBARA BLOCK
LAKE McKAY BASIN
ARUNTA BLOCK
HAMERSLEY BASIN
RAWLINSON BASIN
BANGEMALL BASIN
GASCOYNE BLOCK
MUSGRAVE BLOCK
NORTHAMPTON BLOCK
YILGARN BLOCK
NATURALISTE BLOCK
ALBANY—FRASER PROVINCE
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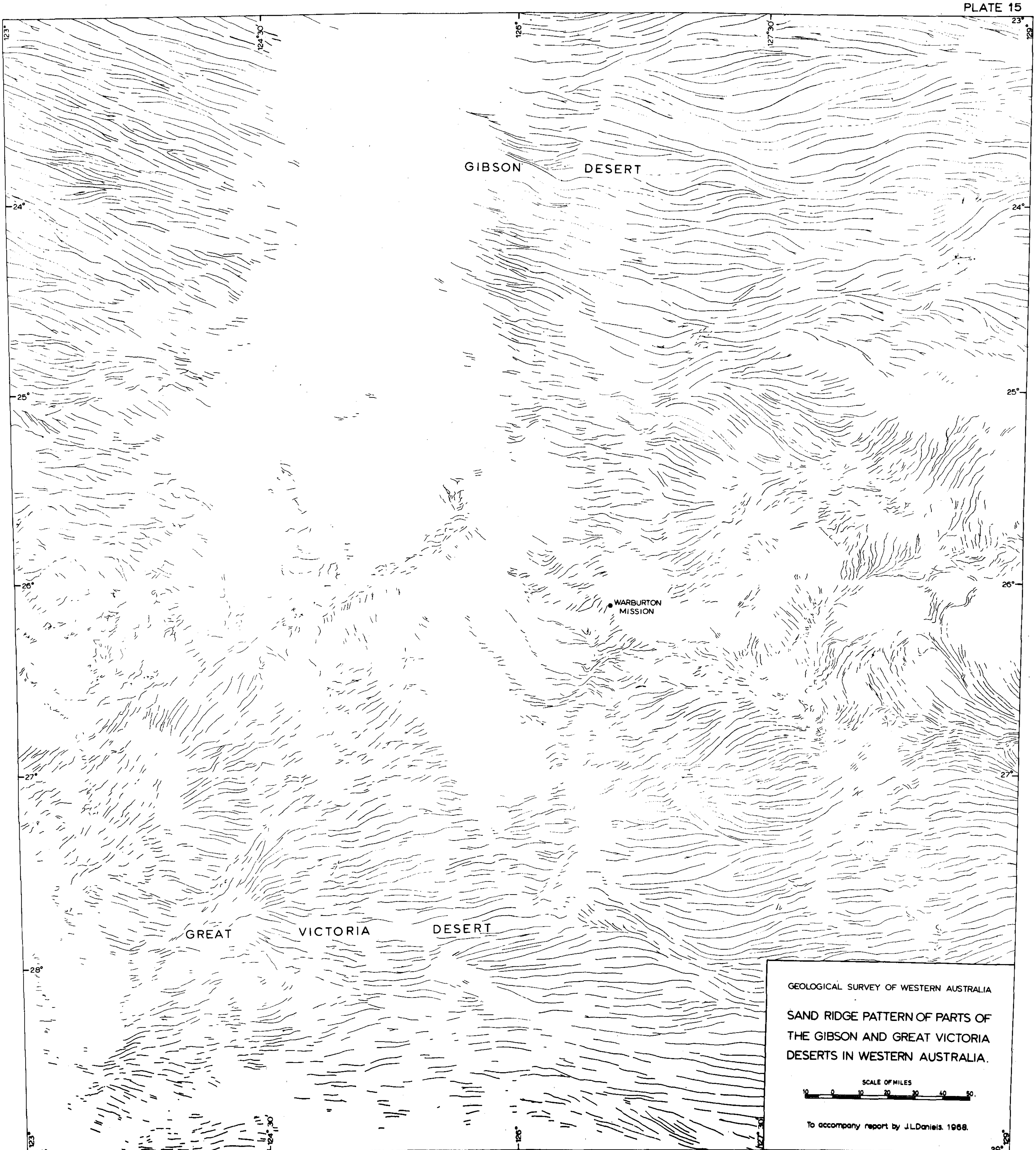
PLATE 15



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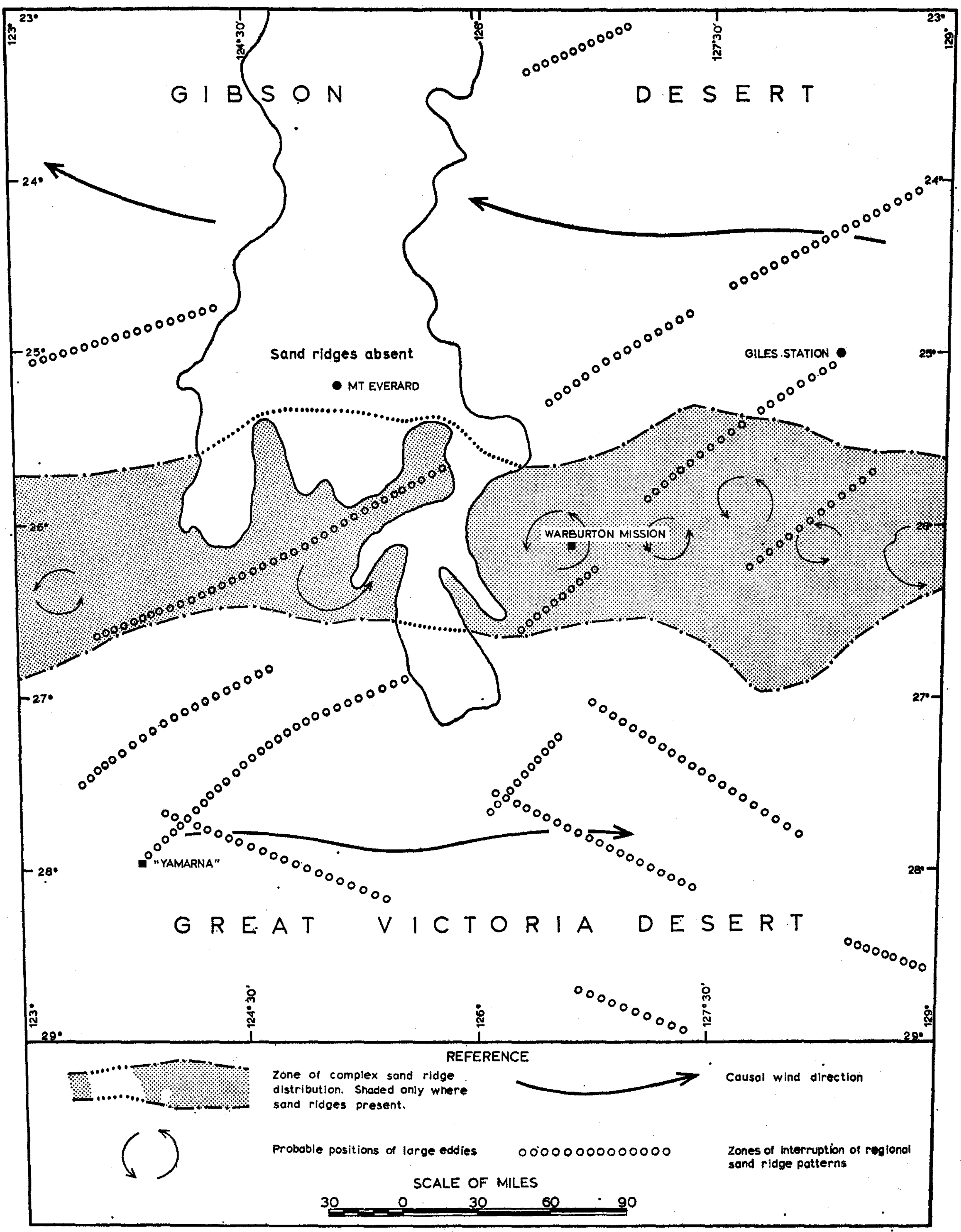


Figure 8. Summary of broad features of sand ridge distribution in the Gibson and Great Victoria Deserts.

STRUCTURAL LAYERING IN THE ARCHAEAN OF THE KURNALPI 1:250,000 SHEET AREA KALGOORLIE REGION

by I. R. Williams

SUMMARY

Regional mapping in the area east and north-east of Kalgoorlie, on the Kurnalpi 1:250,000 Sheet, has led to the setting up of a stratigraphic succession for the Archaean layered rocks. The succession consists of three basic volcanic rock associations which alternate with two associations of mixed acid volcanic and clastic rocks.

The primary control for the lithological associations is considered to be a repetitive igneous cycle. It commences with widespread extrusion of largely basic rocks interbedded with fine-grained clastic rocks and concomitantly intruded by basic and ultramafic rocks. This is followed and gradually replaced by acid effusion and intrusion in more restricted areas and by the deposition of thick clastic sequences marginal to, interlayered with, and overlaying, the acid volcanic rocks. Prominent beds of chert and banded iron formation are commonly present between the acid volcanic clastic association and the overlying basic volcanic association, and these are interpreted as representing a period of quiescence between succeeding volcanic cycles.

INTRODUCTION

The complexity of Archaean stratigraphy is well illustrated in the layered succession of the Kurnalpi 1:250,000 sheet area. The typical lenticular form of the bedding together with facies change and dissimilarity of lithology across simple structures make it difficult to present type and measured sections. A detailed description of the lithological units and type areas will be presented in the explanatory notes of the Kurnalpi 1:250,000 sheet area.

The complex stratigraphy is more easily understood if demonstrably related rocks are grouped together to form lithological associations. The resultant continuity of the associations in turn facilitates interpretation of the regional structure. The layered succession in this form can be divided into five structurally identifiable associations; basic volcanic associations (greenstone) numbered I, III, V, alternating with acid volcanic—clastic associations (whitestone) numbered II and IV (see Plate 16).

The marginal zones between the five associations were studied in some detail and genetic relationships were established between associations I and II and similarly between III and IV. These relationships are thought to represent volcanic cycles and are numbered 1 to 3 on Plate 16.

The regional extent of these associations outside of the Kurnalpi Sheet is unknown at this stage but a similar relationship is thought to exist throughout the layered rocks of the Kalgoorlie region.

STRATIGRAPHY

The regional distribution of the association is set out in plate 16 together with a generalized description of the main lithology of each association.

The basic volcanic associations I, III, and V are made up of basic to intermediate lavas interbedded with fine-grained pelitic sediments. The ratio of volcanic rocks to sedimentary interbeds varies for any given section but in most cases the volcanic material is the main constituent. Concurrent with deposition, the associations have been intruded by sills and dykes of basic and ultramafic rocks. Minor acid intrusions are present in associations I and III. The basal units of associations III and V (the base of unit I is unknown on the Kurnalpi Sheet) commonly include thick beds of ferruginous chert, jaspilite, and banded iron formation, together with some minor coarse-grained fragmental rocks. Each basic association is estimated to be between 5,000 and 15,000 feet thick.

The acid volcanic—clastic associations II and IV are both divided into two facies which are contemporaneous but spatially separate. One facies consists of acid volcanic complexes that are made up of intermediate and acid lavas, breccias, agglomerates, and large quantities of pyroclastic material. The complexes are locally very thick but are restricted in area. They are flanked by oligomictic conglomerates (clasts are acid volcanic material) which appear to be derived from the complexes by contemporaneous erosion (Horwitz and others, 1967). Thick clastic deposits make up the second part of each association. These deposits consist of greywacke, interbedded shales, siltstone, and sandstone and include thick lenses of polymictic conglomerate. The conglomerates contain a wide variety of rock types that include clasts of acid volcanic and intrusive rock, sediment, chert, jaspilite, and basic volcanic and intrusive rocks. Local disconformities are common within this type of association. Because of the mixed nature of the acid—clastic associations, the total thickness varies considerably but is thought to reach a maximum of about 30,000 feet in each case.

DISCUSSION

The alternate basic or acid—clastic layers show many lithological similarities. This broad similarity is interpreted as a repetition in conditions of sedimentation and volcanicity which can be extended to include the complete volcanic cycle (see Plate 16).

There are several small features that help to distinguish one sequence from another. Basic associations I and III contain sills and dykes of acid porphyry rocks; these are lacking in association V. This observation is also recorded by Horwitz and Sofoulis (1965) who describe a suite of basic rocks that truncate acid porphyry rocks. Basic association III contains a higher percentage of fine-grained sediments than I or V. The sediments include minor occurrences of fuchsitic schist.

Acid volcanic complexes are more numerous in association II and hence there is a higher proportion of derived and primary volcanic material in II than in association IV. Conversely there is a greater proportion of foreign clastic material in association IV than in II. Thick lenses of polymictic conglomerate are a prominent feature of association IV, whereas these are absent or only poorly developed in association II.

The broad structural trends are shown on Plate 16. A difference in fold styles between the associations suggest that unconformities probably lie between succeeding volcanic cycles, for example between cycles 1 and 2. Additional evidence gathered from a study of the marginal areas between the volcanic cycles shows that convergence and disappearance of units are present in this region. Local unconformities are also present within a cycle and may reach major proportions as in the area north of Bulong where association IV rests on eroded rock of association II.

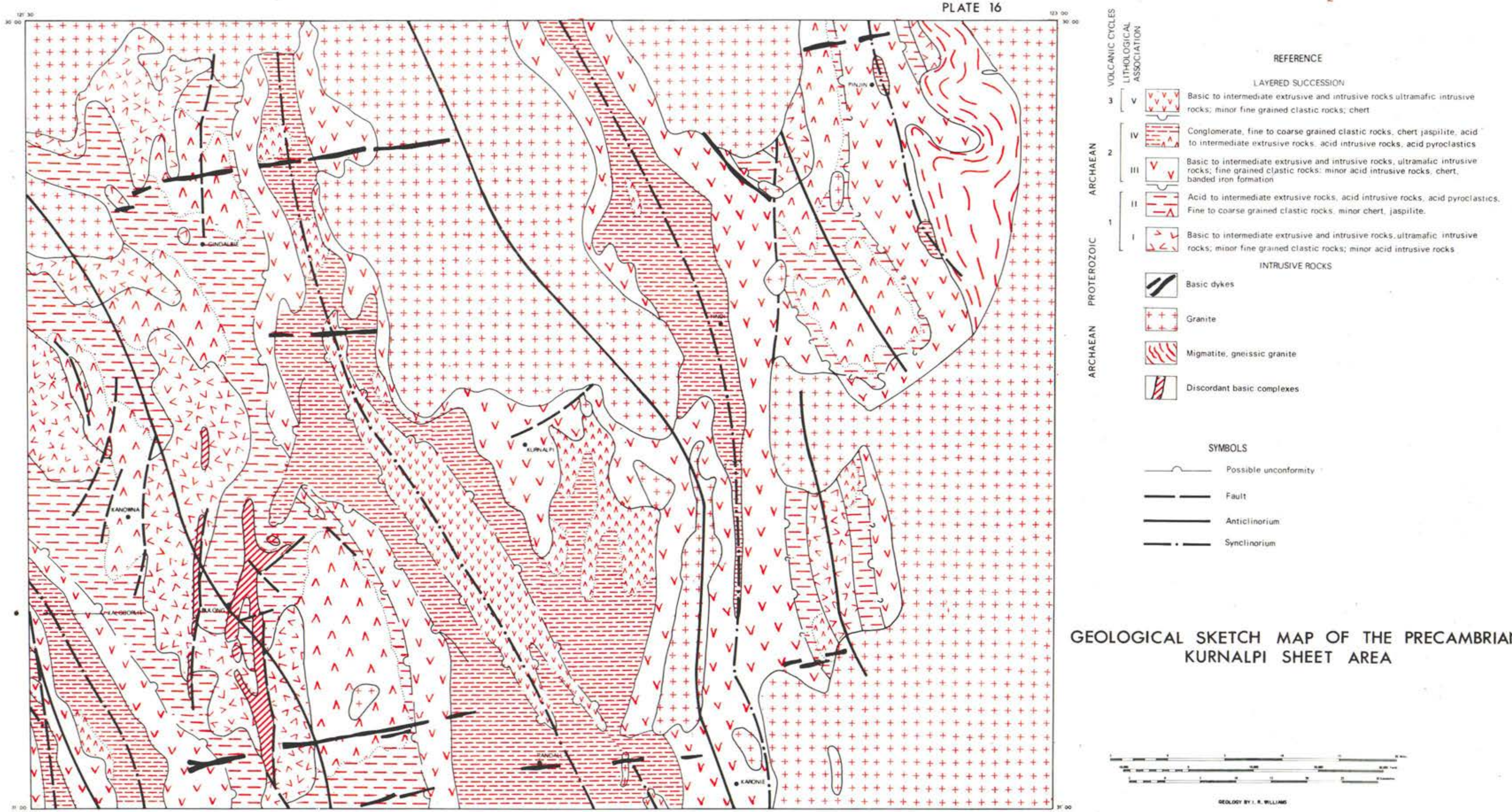
The recognition of unconformities is difficult and it is suspected that they are not continuous for long distances. They appear to be more obvious in the western half of the Kurnalpi Sheet.

CONCLUSION

The recognition of lithological association has led to a clearer understanding of the geological enrivonment and the Archaean palaeogeography in the region. A possible analogous situation may be present in some recent island arc environments, particularly where volcanic centres show rhythmic changes in composition from basic to acid lavas.

Two major points have been established from the field mapping.

PLATE 16



GEOLOGICAL SKETCH MAP OF THE PRECAMBRIAN KURNALPI SHEET AREA

(1) the grouping of rocks into lithological associations has enabled the setting up of a stratigraphic succession;

(2) the establishment of repetition in the Archaean environment has led to the recognition of volcanic cycles.

The validity of lithological associations as a workable concept has still to be fully examined.

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THE PRECAMBRIAN GEOLOGY BETWEEN ZANTHUS AND ISRAELITE BAY, WESTERN AUSTRALIA

by J. J. G. Doepel

ABSTRACT

Granites and metamorphic rocks, between Zanthus and Israelite Bay, in the southeast corner of the Precambrian Shield of Western Australia, are in a layered sequence folded into a large anticline in the core of which the lowest exposed unit is composed of the metamorphic rocks of the Fraser Range. Higher units include Proterozoic granites and metamorphosed sediments. The highest outcropping unit, exposed at the south coast, is a gneissic complex containing rocks believed to be Archaean.

INTRODUCTION

Regional mapping between Zanthus, a siding on the Trans-Australian Railway about 130 miles east of Kalgoorlie, and Israelite Bay, about 180 miles to the south and on the south coast, has shown that the Precambrian of the area can be broadly subdivided into a number of structural layers or units, as shown in Plate 17. The units trend southwest with a general steep dip to the southeast, and are covered to the northeast by the Tertiary sediments of the Eucla Basin. The region is at the eastern end of exposure of the Albany—Fraser Range Province.

SEQUENCE

Progressing across the layering, from the southeast to the northwest, the units are, in order:

(1) A strongly folded and metamorphosed complex in which at least two generations of granitic material cut remnants of quartzites and schists and are cut by basic dykes. Pegmatites cut the basic dykes.

(2) An augen gneiss; a metamorphosed biotite-rich lath granite which is thought to represent a metamorphosed margin to unit 3. It was cut before metamorphism by aplites, pegmatites and occasional basic dykes.

(3) A granite, often with feldspar phenocrysts, which in places has an imposed metamorphic foliation marked by biotite alignment and deformation of the feldspar phenocrysts.

(4) Steeply dipping quartzites and quartz-mica schists which occur in what are interpreted as two separate synclines. Only one closure, at the north end of the southern structure, is, however, exposed and no contact with granite is seen. Quartz veins are the only rocks observed cutting these metamorphosed sediments and it is unknown whether they are unconformable on the granites or folded rafts in the granites.

(5) Mixed granites. Fine and medium-grained metamorphosed granitic rocks are cut by lath granites of units 3 and 6 and both of these by leucocratic granite of unit 7.

(6) A granite, often with feldspar phenocrysts similar to that of unit 3.

(7) Equigranular leucocratic granite of varying grain size and degree of foliation. It contains many thin rafts of biotite-rich granular rock. It is younger than the lath granite which it invades with numerout dykes that trend north and northeast. Many aplites and microgranites cutting the gneissic granites and the granulites of the Fraser Range are thought to be related to this granite. These aplites and microgranites have themselves undergone some metamorphism.

(8) A garnet-biotite-quartz-feldspar gneiss in which feldspar augen are presumably after original feldspar laths in a lath granite. It intrudes basic rock near Newman Rock and is intruded by leucocratic granite. It is cut by northeast-striking bands of mylonite.

(9) The metamorphic complex of the Fraser Range contains basic granulites, cut, before or during metamorphism, by acid veins and dykes, some of which have a rapakivi texture. Later aplites cut these rocks parallel to the metamorphic foliation. The granulites contain pods of metamorphosed norite which are either less affected residuals or intrusions emplaced during metamorphism. A zone of amphibolite grade metamorphism is present along the western side of the complex. The acid dykes and the aplites have undergone cataclasis of varying degree and several bands of mylonite are present at the western margin of the complex. The other margins are nowhere exposed but may well also be zones of shear or of faulting.

Compston and Arriens (1968) report that "The granulite facies rocks . . . give an isochron of 1330 ± 15 m.y., with initial $^{87}Sr/^{86}Sr$ of 0.705 ± .001". They also report that, "studies now in progress suggest that the flanking augen gneisses that lie on either side of the granulite-facies rocks . . . have ages several hundred million years older than the granulites, whereas the granitic rocks further east at Balladonia could be younger". It is likely that both the lath granite of unit 6 and the leucocratic granite of unit 7 were included in this last younger group.

(10) Mixed granites. At least three ages of granites are present.

(11) About 6 miles south of Coonana the granites are cut by strong north-north-east shearing, and a sheared serpentinite, possibly intrusive, is present in this zone.

(12) About 30 miles north of Israelite Bay a thin unmetamorphosed feldspar-phyric

dolerite dyke, trending 056°, intrudes metamorphosed granites.

No basic dykes have been observed cutting the lath granites of units 3 and 6, the leucocratic granite of unit 7, or the gneissic granite of unit 8.

STRUCTURE.

Morgan, Horwitz and Sanders (1968), describing the structural layering of the Precambrian rocks of the Archipelago of the Recherche, found that mixed gneisses, believed to be Archaean, which may be correlated with unit 1 of this paper, were the highest exposed rocks of a broad southwest plunging anticlinorium. A lath granite, unit 6 of this paper, was the deepest rock exposed in the area described by them. It is here suggested that units 7, 8 and 9 are successively still lower layers; unit 9, the metamorphics of the Fraser Range, being the core of the anticlinorium. It is not suggested that the mixed granites of unit 10 are the direct equivalent of any one of the units to the southeast.

The presence of basic dykes in the gneisses and their absence in the lower units is continued to the west (Morgan, Horwitz and Sanders, 1968).

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Morgan, K. H., Horwitz, R. C., the Sanders, C. C., 1968, Structural layering of the rocks of the Archipelago of the Recherche: West. Australia Geol. Survey Ann. Rept. 1967, pp.44-45.

INVESTIGATION OF MINISTERIAL RESERVE 4538H, LAKE YINDARLGOODA, BULONG DISTRICT, W.A.

by J. Sofoulis, X. K. Williams, and D. L. Rowston

ABSTRACT

The gossans on Ministerial Reserve 4538H are interpreted as visible geological indications of stratiform sulphide concentrations and are presumed to have been formed in place by the oxidation of disseminated or massive sulphides, probably pyrite.

Although the geological environment is favourable for base metal mineralization, an integrated geological, geochemical, and geophysical survey indicated no significant metal sulphide concentrations other than iron. However, some anomalous geochemical and geophysical results were obtained locally from the main gossan and from the adjacent lake floor area.

A diamond drilling programme to test some of these anomalies has been outlined.

INTRODUCTION

Ministerial Reserve 4538H was created with the intention that the Geological Survey of Western Australia carry out an integrated geological, geochemical and geophysical investigation on the limonitic gossans contained therein, to ascertain whether such gossans indicate the presence of base metal sulphides.

The Reserve lies within Hampton Hill Station owned and operated by C. B. Jones and Sons of Bulong (19 miles east of Kalgoorlie). The gossans occur near Rocky Dam, on the northwestern margin of Lake Yindarlgooda, approximately 19 miles northeast of the station. Access over the area is by graded station tracks as shown on the locality map (Plate 18).

Air photographs, at a scale of 1,000 feet to 1 inch, and photo enlargements, at a scale of 200 feet to 1 inch, were used for geological mapping of the Reserve area and for the more detailed investigation of the main gossan zone (outline dotted on the locality map). The initial phase of the programme was aimed at defining the geology and structure of the area (J. Sofoulis) with subsequent geochemical and geophysical work over selected parts of the main gossan zone (X. K. Williams and D. L. Rowston respectively). The field work was carried our during the period July to September, 1968.

A more detailed report on this Reserve is given by the same authors in G.S.W.A. Record 1968/17.

PHYSICAL FEATURES

The general area, with a rainfall 9 to 10 inches per annum, can be described as semi-arid and is characterized by salt lakes and remnant soil plains. Ferruginous gossans, associated with banded chert marginal to Lake Yindarlgooda dominate the topography as scrub-covered strike ridges extending discontinuously down the length of the Reserve. Topographic relief in these localities is up to 200 feet. There are other prominent chert bands and some smaller gossans in the northwestern part of the Reserve area, west of the main gossan line. An elevated plateau surface developed over conglomerate in the northern part of the Reserve is delimited by a prominent escarpment up to 100 feet high.

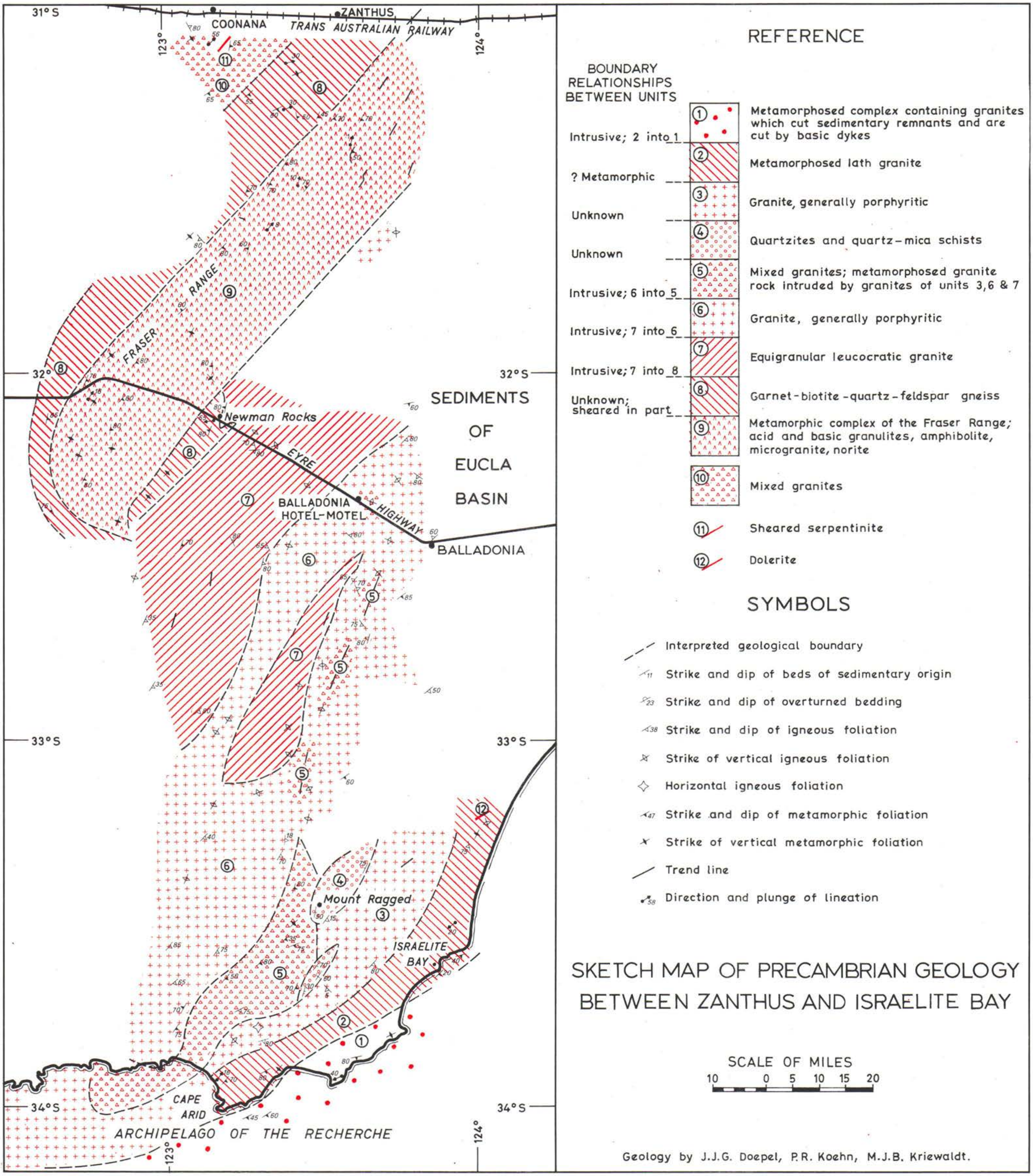
Elsewhere the Reserve area is of low relief, with small erosion escarpments (to 50 feet) in the dissected parts; intervening areas of soil-covered plains support eucalypt and acacia woodlands interspersed with salt bush and blue bush meadows. These areas contain scattered exposures of weathered bedrock and widespread veneers of quartz debris derived from the more resistant quartz dykes. The eastern and southern parts of the Reserve area are occupied by bare salt lake floors of Lake Yindarlgooda.

STRATIGRAPHY AND GEOLOGICAL SETTING

Three major Archaean units separated by probable unconformities have been recognized in the Reserve area. These units are equated with rock association units II, III, and IV as mapped on the Kurnalpi sheet by Williams (1969), (see Table 1). Their distribution over the Reserve area is shown on Plate 18.

TABLE 1. ROCK ASSOCIATION UNITS

Unit	Kurnalpi 1 : 250,000 Sheet Area (After Williams, 1969)	Ministerial Reserve 4538H Area
V	Basic to intermediate extrusive and intrusive rocks; ultrabasic intrusive rocks; minor fine-grained clastic rocks, chert	Unit not represented
IV	Conglomerate, fine to coarse-grained clastic rocks; chert, jaspilite, acid to intermediate extrusive rocks and acid intrusive rocks, acid pyroclastics	Conglomerate, fine to coarse-grained clastic rocks
III	Basic to intermediate extrusive and intrusive rocks, ultrabasic intrusive rocks, fine-grained clastic rocks; minor acid intrusives, chert, banded iron formation	Basic extrusive and intrusive rocks, dolomite, graphitic shales, siltstone, conglomerate ?tuffs, chert
II	Acid to intermediate extrusive rocks and acid intrusive rocks, fine to coarse-grained clastic rocks, minor chert, jaspilite	Acid to intermediate extrusive rocks, fine to coarse-grained clastic rocks
I	Basic to intermediate extrusive and intrusive rocks, ultrabasic intrusive rocks; minor fine-grained clastic rocks; minor acid intrusives	Unit not represented



SKETCH MAP OF PRECAMBRIAN GEOLOGY BETWEEN ZANTHUS AND ISRAELITE BAY

Geology by J.J.G. Doepel, P.R. Koehn, M.J.B. Kriewaldt.

UNIT II

Acid volcanics are the oldest rocks exposed in the Reserve area. These are mainly sericitic, chloritic schist and phyllite, and are confined to to the area south and southeast of Rocky Dam, where they form a thick pile at the base of the unit. Intermediate volcanics in the middle and upper part of the sequence are separated by, or interfinger with, pyroclastics, tuffs, and fine and coarse-grained clastics. Closely interstratified tuffs are gradational with the clastics and are discontinuous laterally. Thicker beds of clastic rocks (e.g. west of main gossan line) include greywacke, sandstone, arkose, and conglomerate. Observations on grading and cross bedding confirm that the sediments are facing east and that they are right-way up.

UNIT III

Chert beds and their associated limonitic gossans are interbedded with pelitic schists and other recognizable clastic sediments in the lower part of this unit. The uppermost chert beds are commonly pyritic with variable concentrations of single, perfectly formed crystals, now replaced by limonite.

Broad belts of altered basic volcanic rocks (meta-basalt and gabbro) with interbeds or stratigraphic equivalents of siltstone, shale, greywacke, dolomitic limestone, graphitic beds, and conglomerate, are found in the upper part of this sequence.

An unconformable relationship between this unit and the underlying unit is inferred from the slight discordance in bedding and schistosity noted between rocks of Unit II and those of Unit III, and from the fact that the various volcanic and sedimentary phases of Unit II are progressively truncated by rocks of Unit III along the southeastern extension into Lake Yindarlgooda.

UNIT IV

Conglomerate with interbedded greywacke of turbidite affinities rests with structural discordance on the rocks of Units III and II in the northern and northwestern part of the Reserve area. The conglomerate consists of an assortment of closely packed, well-rounded pebbles, cobbles and boulders, which collectively comprise up to 30 per cent of the rock. The matrix is coarse, gritty greywacke to sub-greywacke which also forms thin and thick bands separating layers and lenses of conglomerates.

The contact between this Unit and the underlying Unit is concordant in the southeastern part of the Reserve area, but to the northwest the conglomerates and greywackes of Unit IV fill hollows or embayments in the old erosion surface formed on Units II and III.

STRUCTURE

Isoclinal fold structures are aligned north-northwesterly and correspond to the regional fold trends observed in the eastern goldfield areas. The strata dip moderately to steeply northeast, so it is probable that some of the folds, such as those in the western part of the Reserve area, are overturned to the northeast.

Lineations, as indicated by alignment of mineral grains, plunge 30 to 40 degrees in a north-northwesterly direction and correspond in amount and direction to minor drag folds observed. The folded chert beds with which the gossans are associated, lie on an eastern limb of a north-northwesterly plunging anticline, while the repeated chert beds further west constitute a complex synclinorial trough similarly plunging north-northwest.

Two major sets of steeply dipping faults at right angles to each other, have affected all units. These trend north-northeast and west-northwest and are oblique to the strike of bedding. The faults were probably formed at the same time by the same diastrophic compressional forces. An alternation between the two fault directions is noted along the major chert belts. Faults of north-northeast trend predominate where strata are convex to the southwest, whilst those of west-northwest trend predominate where strata are convex towards the northeast.

In these faults, the horizontal component of movement is small, but it seems probable that vertical movements were more severe, causing truncations or divergencies in the rock belts. Many of the faults are quartz-filled or have quartz lenses along their strike extensions.

Fault lineaments, such as those prominent on the lake floors, are often continuous with known fault lines, and are locally marked by discontinuous quartz lenses.

LIMONITIC GOSSANS

Limonitic gossans are associated with the pyritic schists and cherts of the lower part of Unit III. This geological environment has similar characteristics to other Shield areas in which base metal deposits have been found. These gossans are interpreted as visible geological indications of stratiform sulphide concentrations and have presumably formed in place by oxidation of disseminated or massive sulphides, probably pyrite. They are classified as indigenous in the sense of Hill (1962) since they simulate the shape and structure of ore bodies.

The indigenous gossans range in thickness from a few inches up to 20 feet or more and are discontinuous along strike, with separate lenses being from a few feet to more than a thousand feet long. Their size however may not necessarily be proportional to that of the source sulphide deposits. The most common variety of gossan is a lightweight, slaggy, and spongy limonite which is very tough and hard to break with a hammer. The colour of these gossons is mainly dark reddish-brown, usually with a black patina, and locally with limonitic orange coatings. Larger voids within the gossans are commonly lined with microbotryoidal structures and microscopic films of irridescent yellow, red, green and blue-black limonite. Minor box works are mainly of silica, deposited as a very fine vein filling of microcrystalline quartz and arranged in small radial or comb structures.

More exotic vuggy gossans have a high porosity and form a spongy type of gossan resembling brown and yellow pumice. These are interpreted as a superficial form of indigenous gossan. Discontinuous and narrow ferruginous gossans cutting across structure are migrative forms of gossan probably related to ferruginization or oxidation of concentrated sulphides along fault or shear lines. Other thin gossanous lines paralleling the bedding are associated with sulphide-bearing graphite schists and dolomite/graphite beds.

Prominent banding in the indigenous gossan is attributed to the original bedding planes of the host rock and in many instances the gossan may contain thin bands of pyritic jaspilite or chert, and narrow schist zones.

Isolated patches of limonitic gossan form strike extensions of the indigenous type or may appear as separate masses that are apparently in place and independent of the main gossan lines. Minor turquoise (a hydrous phosphate of aluminium and copper) was recorded below the main gossan in the northwestern part of the area. (Grid 1). The upper cherts and associated sediments commonly contain pyrite casts and limonite pseudomorphs after pyrite. These are mainly concentrated along the schist and chert foliae close to the developed gossan. However, no surface indications of copper or other metal sulphides other than iron were observed in the gossan.

GEOCHEMISTRY

SAMPLING

Two groups of samples were collected for geochemical analysis. Gossan samples were taken to obtain information about the gossan itself, and to locate possible indications of underlying economic base metal mineralization. Lake floor samples were collected from two grids (1 and 5) in which geophysical work had already been done and some significant electromagnetic anomalies found. Correlations between the geophysical and geochemical results were sought, also any interdependence of the gossan and lake floor results.

Representative samples were collected at intervals of 100 to 200 feet along the length of the main gossan, and from smaller gossans occurring close to, or as branches of, the main one. Other isolated gossans within the Reserve area were also sampled. The localities and results are shown on the geological map (plate 18).

The lake floor samples were collected at intervals of 25 feet from 18 lines in the two grids, mid-way between the geophysical centres to avoid the possibility of contamination. At each locality the surficial material was removed and the sample collected from the weathered sub-outcrop, usually at a depth of 3 to 12 inches. The samples were dried and sieved prior to analysis of the fine fraction.

RESULTS

All samples were submitted to the Government Chemical Laboratories for analysis by atomic absorption spectroscopy. The results from the gossan samples are shown on Plate 18, and anomalous samples from Grid 5 in Table 2.

The mean concentrations of copper, cobalt, nickel, and lead in the gossan are similar to or higher than those from the lake floor samples (Table 3). The concentration of zinc is higher in the lake floor samples suggesting possible accumulation by weathering, as zinc is the most mobile of the elements studied. Silver is relatively immobile, its mobility being reduced by co-precipitation with manganese, and thus occurs in greater concentration in the gossan.

The anomalous results from samples of the gossan fall into two groups, both of copper, cobalt, zinc, lead, and silver, no nickel (see Table 4). One group is in and north of Grid 1, and the other in and south of Grid 5. At the southern end of the gossan there are several copper anomalies. Another gossanous area, in the northwest of the temporary reserve, shows significant nickel, cobalt, and zinc concentrations.

Of the lake floor samples, the average and range of metal content of samples from Grid 5 is higher than for samples from Grid 1. Silver is the only element whose mean concentration is higher in Grid 1 than Grid 5. Lead, with which silver is often associated, is only slightly higher in Grid 5. The mean concentration of the other elements is between 2.4 and 3.2 times higher in Grid 5. The ranges of concentration of copper, cobalt, nickel, and zinc are greater in Grid 5, and of silver and lead in Grid 1.

There are very few anomalous results from Grid 1. Samples with anomalous lead and silver occur in lines 4N and 6S and follow the occurrence of gossanous rocks, which also contain high concentrations of lead and silver. Other anomalous samples, in lines 4N and O, are associated with gossanous outcrops and graphitic dolomite. There are a few scattered copper and zinc anomalies which are probably local variations and of little significance.

Grid 5 contains one major anomaly (Table 2) between and including lines 11S and 15S. The anomaly is essentially copper, cobalt, nickel, and zinc, with some lead. It extends from a width of 25 feet on line 10S to a maximum of 350 feet on line 15S, and continues on through line 17S. There are some scattered cobalt and nickel concentrations in line 19S which are possibly related to its proximity to the basalt. Of the gossan samples in and near Grid 5, the four collected between lines 10S and 17S have anomalous concentrations of lead, one has some copper, and the sample from line 19S has anomalous cobalt.

There are other isolated anomalies, on lines 3S, 5S, 7S, 8S, 9S, and 10S; these may be associated with the main anomaly, but are probably local variations and of minor significance.

The main anomaly may either be caused by the weathering processes that produced the gossan, or by the presence of anomalous underground concentrations of these elements. If the gossan at this point had high base metal concentrations initially the weathering effects of decomposition and erosion would have caused these elements to be removed from the acidic environment of the gossan and deposited on the lake floor. However, at this point the gossan forms a slight topographical arc and this could cause an accumulation of drainage material in the area; further dispersion would be limited by the higher pH on the lake floor, relative to the gossan. If this is the origin of the anomaly, no anomaly within the gossan is necessarily indicated. Possible subsurface sources of the anomaly are:

(a) leakage anomalies from underlying sulphides that give rise to the present gossan,

(b) the presence of underlying, near surface rocks with high base metal content, such as the graphitic shale and dolomite.

From the results obtained it is clear that the two grid areas are adjacent to gossans that are relatively rich in base metals. The concentrations obtained are low compared to others found in the Kalgoorlie District, but they were mainly from areas of basic and ultrabasic country rock, where base metal concentrations are normally high, even in background areas. On the other hand, acid rocks in the Reserve area have relatively low background levels of base metal content, so lower intensity anomalies may be correspondingly more significant. The very high cobalt concentrations are interesting, particularly as less work has been done on cobalt than on the other elements, in this district.

TABLE 2. ANOMOLOUS RESULTS ON LINES 11S AND 15S GRIDS

Sample Nos.	Concentrations in parts per million					
	Ni	Zn	Co	Pb	Ag	Cu
Line 11						
B 114	75	1000*	110*	80	x	300
115	75	990*	85	60	1	260
116	160*	1200*	280*	200*	1	400*
117	160*	875*	400*	120*	1	480*
118	140	580	70	90	1	450*
119	120	360	95	120*	x	460*
120	160*	1200*	270*	110	x	320*
121	80	250	65	90	2	270
122	175*	440	115*	100	1	190
123	175*	920*	125*	100	1	160
A' 124	200*	840*	185*	100	1	440*
Line 15						
B 133	50	260	30	120*	x	479*
134	100	150	50	90	x	205
135	360*	1900*	170*	100	1	625*
136	150	550	110*	80	1	490*
137	200*	420	55	70	1	180
138	400*	1550*	300*	40	1	630*
139	400*	1270*	480*	80	1	260
140	175*	770*	120*	80	x	320*
141	780*	2120*	1060*	60	x	510*
142	650*	820*	185*	70	1	275
143	650*	2100*	900*	50	x	1100*
144	180*	650	140*	40	x	270
145	480*	460	10	50	1	1100*
B' 146	80	130	55	120*	1	170

* = anomalous results.

TABLE 3. MEAN AND RANGE OF RESULTS

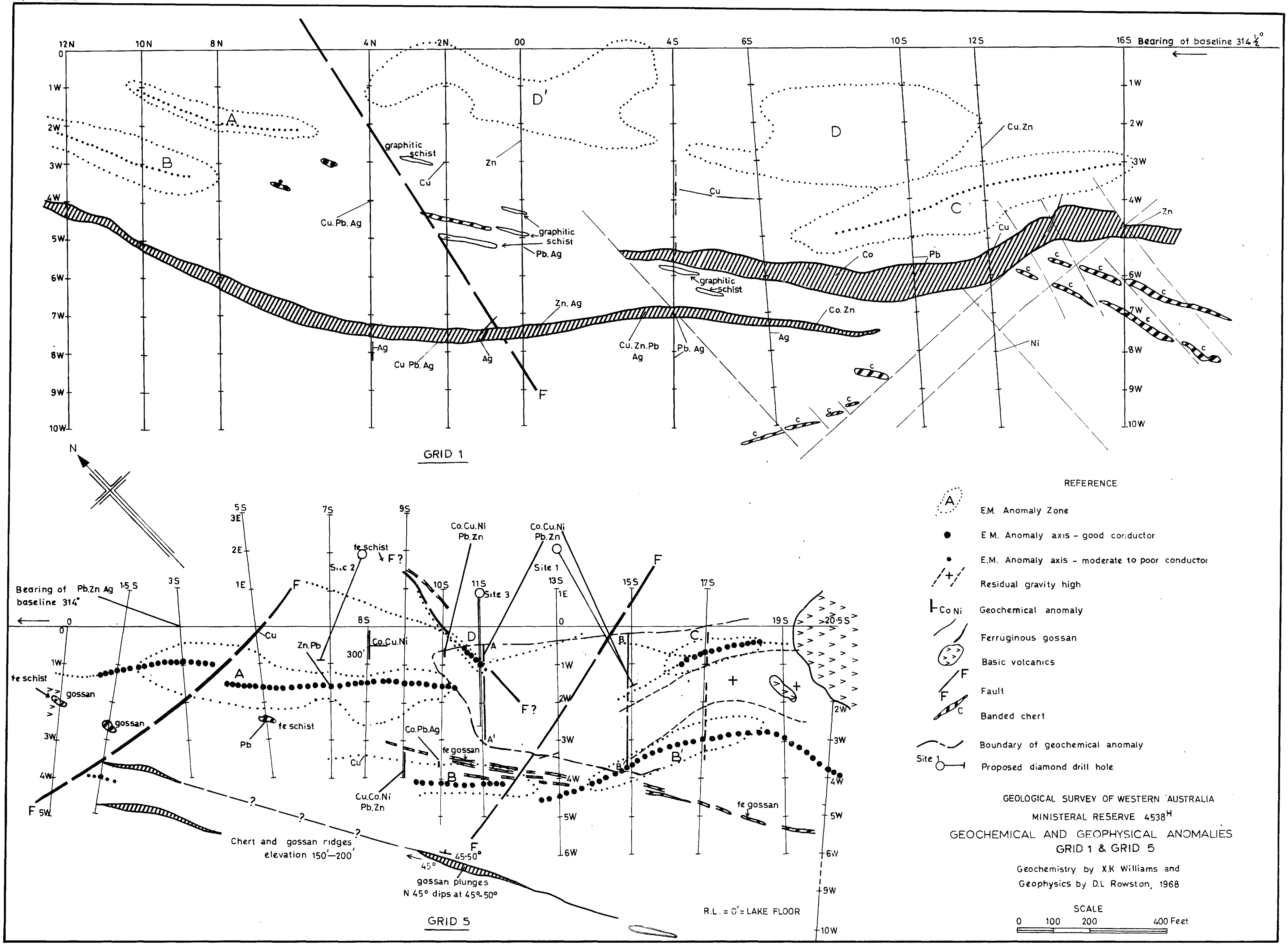
Metal	Gossan		Grid 1		Grid 5	
	Mean p.p.m.	Range p.p.m.	Mean p.p.m.	Range p.p.m.	Mean p.p.m.	Range p.p.m.
Cu	153	15–400	68	5–550	177	0–1100
Co	65	5–60	18	0–100	58	0–1060
Ni	68	20–280	34	0–180	81	0–780
Zn	152	5–850	117	5–800	291	0–2400
Pb	62	20–400	46	0–250	59	0–200
Ag	1·4	0–6	0·77	0–4	0·46	0–3

TABLE 4. THRESHOLD CONCENTRATIONS AND DISTRIBUTION OF RESULTS

Metal	Gossan		Lake Floor	
	Threshold p.p.m.	Anomalous results per cent.	Threshold p.p.m.	Anomalous Results per cent.
Cu	270	12·4	310	5·8
Co	30	11·5	100	5·9
Ni	140	6·2	130	7·6
Zn	300	10·6	700	4·0
Pb	130	8·0	110	4·3
Ag	3	8·0	2	4·3

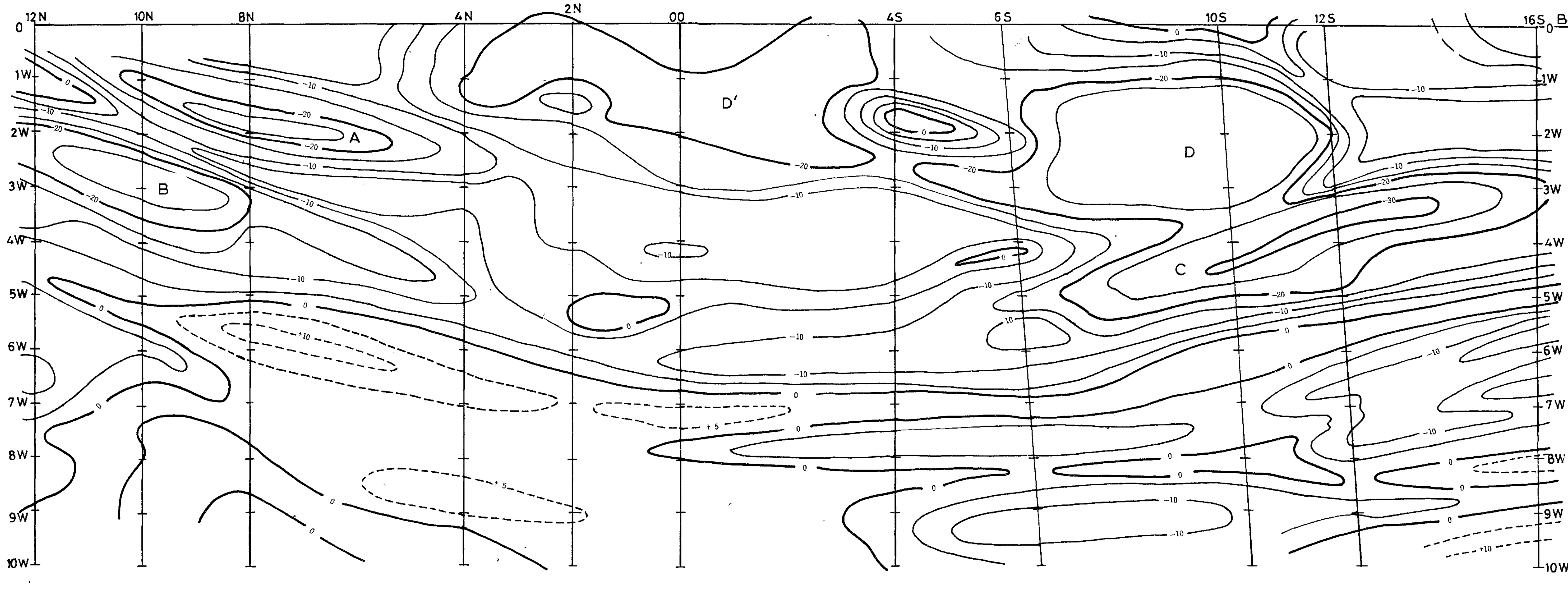
PLATE 18

10571

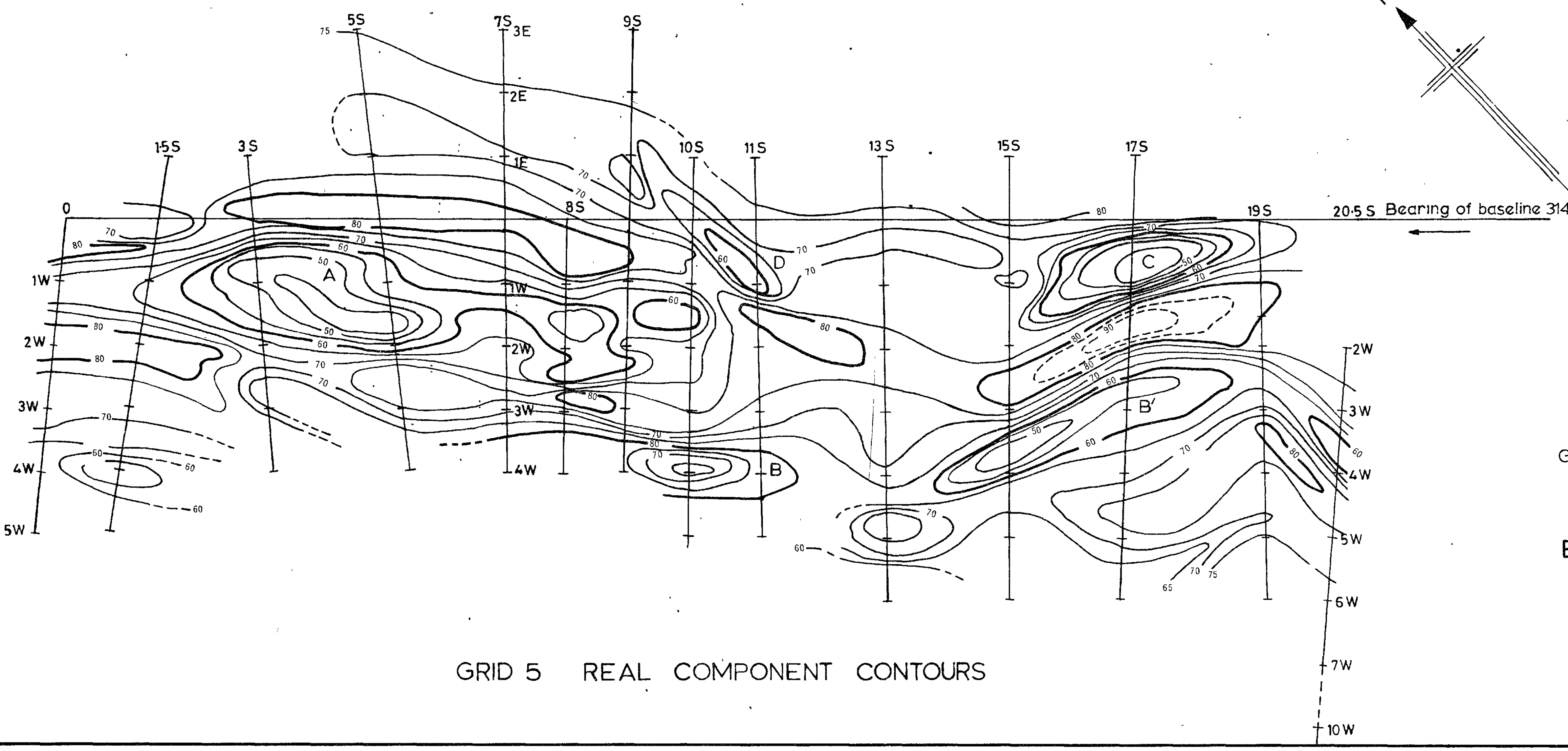

GRID 1
GRID 5
Bearing of baseline 314½°
Bearing of baseline 314°
graphitic schist
Cu. Pb. Ag
Cu Pb. Ag
Zn. Ag
Cu. Zn. Pb Ag
Pb. Ag
Co. Zn
Cu. Zn
Ni
fe schist
gossan
Co.Cu.Ni Pb.Zn
Site 1
Site 2
Site 3
Co.Pb.Ag
fe gossan
Cu.Co.Ni Pb.Zn
Chert and gossan ridges elevation 150'—200'
gossan plunges N 45° dips at 45°-50°
R.L. = 0' = LAKE FLOOR
REFERENCE
E.M. Anomaly Zone
E.M. Anomaly axis - good conductor
E.M. Anomaly axis - moderate to poor conductor
Residual gravity high
Geochemical anomaly
Ferruginous gossan
Basic volcanics
Fault
Banded chert
Boundary of geochemical anomaly
Proposed diamond drill hole
GEOLOGICAL SURVEY OF WESTERN AUSTRALIA
MINISTERAL RESERVE 4538H
GEOCHEMICAL AND GEOPHYSICAL ANOMALIES
GRID 1 & GRID 5
Geochemistry by X.K Williams and
Geophysics by D.L Rowston, 1968
SCALE
0 100 200 400 Feet

10573

PLATE 20



GRID 1 IMAGINARY COMPONENT CONTOURS



GRID 5 REAL COMPONENT CONTOURS

NOTES
ABEM EM GUN EQUIPMENT
COIL SPACING 100 feet
FREQUENCY 440 cps
STATION INTERVAL 25 feet
CONTOUR INTERVAL R and I 5%
VERTICAL DIPOLE IN-LINE ARRAY

GEOLOGICAL SURVEY OF WESTERN AUSTRALIA

MINISTERIAL RESERVE 4538H

ELECTROMAGNETIC CONTOURS
GRID 1 and GRID 5

SCALE
0 100 200 400 FEET

Field work by D.L. Rowston, Sept. 1968.

10574

GEOPHYSICS

The geophysical phase of the investigations which included magnetic, electromagnetic self potential, and gravity methods, was restriced to several small grids over the more interesting outcrops of ferruginous gossan. The localities of Grids 1, 2, 3, 5, and 6 are shown on the geological map (Plate 18). Grid coordinates with respect to an arbitrary grid zero are given in units of 100 feet. For example coordinate 5/17S/6W denotes Grid 5, the traverse 1,700 feet south of the origin and the observation point 600 feet west of the baseline.

DISCUSSION OF RESULTS

Of the four geophysical methods used on Ministerial Reserve 4538H the electromagnetic proved to be the most effective, albeit with the reservation that to this time a metallic sulphide body has not been discovered. There were no obviously significant results from application of the potential and gravity methods and the ground magnetic survey confirmed the aeromagnetic indications that most of the localities were magnetically undisturbed.

The electromagnetic results varied considerably depending on the environment. Pronounced variations in conductivity were generally confined to the lake floor whereas there was little variation in conductivity on the more elevated areas, such as the ridge along which a large part of the main gossan is situated. The conductivity contrasts on the lake are probably enhanced by penetration of saline water into the more porous and deeply weathered rocks; the resistant rocks would thus appear as relatively poor conductors. Although this factor contributes toward the electromagnetic component configurations, the method can still detect other good conductors. For instance most of the graphitic schists in the area coincide with anomalics and there is no reason to believe that massive sulphides cannot be detected.

The most interesting geophysical indications were obtained in Grid 1 and Grid 5, and further discussion will be confined to these areas with reference mainly to the data shown on Plate 19. Plate 20 consists of contour plans of the EM work; the I component for Grid 1 and the R component for Grid 5. The latter are considered more diagnostic for Grid 5, whereas in Grid 1 spurious anomalies from topographic effects over the main gossan confuse the pattern. Conductor axes determined from vector diagrams, and conductive zones, arbitrarily the -20%I and 60%R contours, together with the essential geology and geochemical results are shown on Plate 20.

Grid 1

In general the EM contours exhibit the same linearity and trends as the mapped sediments and volcanic rocks. Practically all the geophysical anomalies are east of the main gossan and these have been designated A, B, C, D, and D', The western side of the layout is markedly free of indications except in the southwest corner, over kaolinitic tuffaceous sediments.

Anomaly C (Plate 20), which extends from about 7S to 16S, represents a narrow conductor dipping steeply to the east; the axis is displaced on the down dip side of the gossan as would be expected if the conductivity were caused by fresh sulphides at depth. A tabular sheet of graphitic slate or schist would produce an equivalent anomaly. As the geochemical assays from the gossan over this sector were not encouraging it is most likely that pyrite is the only sulphide present.

The only other anomalies that may be related to mineralization are A and B in the northern part of the grid. They are due to relatively good conductors but their small dimensions preclude serious consideration. Their alignment with the mapped dolomitic and graphitic beds to the south suggest that those beds may be the sources of the anomalies.

D and D' are broad features unsupported by a real component anomaly and are thus classified as poor conductors; they probably represent either more deeply weathered rocks or broad depressions in the lake, infilled with saline sediments. In view of the lack of supporting evidence from the geochemical survey, anomaly C, which is the only one of interesting proportions in this area, is not recommended as a drilling target.

Grid 5

Investigation of Grid 5 commenced with an examination of the two small limonitic gossans on traverses 00 and 1.5S (Plate 20). The northern extremity of anomaly A was detected, and the grid was then extended to cover the small embayment defined by basic volcanic outcrops at the ends of the baseline. Operations were confined to the lake bed although Line 20.5S was later taken to 10W to test the main gossan.

A thin veneer of sediment prevented effective mapping of the lake floor and, with the exception of several isolated features protruding above the surface, the geology is unknown.

An interesting electromagnetic contour pattern (Plate 19) was obtained over this layout and intensive geochemical sampling was carried out to assist the interpretation of the main anomalies. Contrary to Grid 1, the R component here showed much more detail than the I component which failed to emphasise some of the less prominent features such as the fault cutting anomaly A.

Four anomaly zones have been defined, A, B and B', C, and D.

A is the most outstanding geophysical indication observed to the present on the Reserve. It is attributed to a tabular conductor dipping steeply to the east and has a strike length of 1,000 feet. There are three possible sources for this anomaly, sulphide mineralization, graphitic beds, or saline clay. A projection of the main gossan to the base of weathering, with due allowance for dip and plunge, supports a sulphidic origin. In addition, saline clays should give a more regular pattern and not exhibit the minor flexure corresponding to the fault; anomalies associated with graphitic beds are usually narrow as typified by anomaly B which is attributed to this source.

Unfortunately the geochemical results show only spasmodic and minor base metal values in the vicinity of the zone, and it must be concluded that, like anomaly C in Grid 1, if sulphides do occur they are mainly pyrite.

Anomaly B and the southern continuation of B', are ascribed to a graphitic bed and appear unrelated to the stringers of gossan mapped along the lake margin. Although a southeast-trending fault intersects this anomaly at about 12S there is no marked disclocation of the geophysical zone at this point.

Anomaly C, whilst indicative of a good nearly vertical conductor of limited dimension, has not been assigned an origin. It is roughly parallel to anomaly B', and a weak gravity high indicates that the two are probably separated by basic volcanics.

Because of its transverse strike and the general lack of indications immediately south of Line 11S, anomaly D was originally interpreted as a fault responsible for the abrupt termination of anomaly A. However, with the exceptions of a tenuous relationship to an outcrop of a ferruginous schist and the fact that the northeast strike is common to other faults elsewhere along the gossan, the geological mapping has not supported this belief. The anomaly is minor by geophysical standards but the geochemical results have enhanced its importance.

CONCLUSIONS

The limonitic gossans of Ministerial Reserve 4538H lie in a geological environment which has similar characteristics to other shield areas in which base metal deposits have been found. The gossans are interpreted as visible geological indications of stratiform sulphide concentrations and are presumed to have been formed in place by the oxidation of the disseminated or massive sulphides, probably pyrite.

Although some minor turquoise was recorded stratigraphically below the main gossan (near Grid 1), no relic mineral or boxwork structures indicative of particular metal sulphides other than iron sulphide (pyrite) were detected in the gossans. However, some anomalous geochemical and geophysical results were obtained from the gossan and from the adjacent lake floor areas.

The more intense geophysical and geochemical anomalies are in the lake floor area of Grid 5. These anomalies may be related to the main gossan, or may be attributable to minor gossanous developments associated with sulphide deposits, or sulphide-bearing dolomite/graphite beds. It is noted however, that the higher geochemical values are not necessarily coincident with geophysical anomalies. It is also stressed that the maximum concentrations shown by the geochemical results are not high, and that the presence of economic mineralization, while not ruled out, has not been positively indicated.

A diamond drilling programme based on the geochemical and geophysical results is recommended to test the Grid 5 area. Three proposed holes (Plate 19) are designed to intersect geochemical and geophysical anomalies below the zone of oxidation as well as to test the main gossan in depth. The holes are, in order of preference, at the following sites:

Site 1: Grid 5/13S/2E, to test the geochemical anomaly B/B' and geophysical anomalies B' and C below the zone of oxidation. Hole to have azimuth 194°, depression 45°, and length approximately 600 feet.

Site 2: Grid 5/8S/2E, to test the geophysical anomaly A (probably due to the main gossan), below the zone of oxidation. Hole to have azimuth 245°, depression 45°, and length approximately 500 feet.

Site 3: Grid 5/11S/1E, to investigate the geochemical anomaly A/A' between 100 and 200 feet vertical depth, and possibly geophysical anomaly D and the main gossan zone at depth. Hole to have azimuth 224°, depression 45°, and length approximately 600 feet.

Should the drilling results prove significant, the nickel, cobalt, zinc anomaly detected in a gossanous zone in the northwestern part of the area could also be worth testing.

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THE STRATIGRAPHY OF THE MOUNT TOM PRICE ORE BODY AND ITS IMPLICATION IN THE GENESIS OF IRON ORE

by J. G. Blockley

INTRODUCTION

During a brief visit to Mount Tom Price in 1966, the writer was impressed by the similarity of the shale bands within the hematite ore body to the 'shale' bands in the Dales Gorge Member of the Brockman Iron Formation, and thought that if a correlation could be established, it could be of value in predicting the position of shale throughout the ore body. Later, when a greater thickness of the ore body had been revealed in the open cut, a further examination was made in the company of Dr. A. F. Trendall.

The resident Mine Geologist, Mr. D. McKenna, assisted the work greatly by providing a guide in the mining area, and by supplying a composite section of the ore body compiled from drill logs.

REGIONAL STRATIGRAPHY

Mapping by geologists of the Geological Survey of Western Australia and C.R.A. Exploration Pty. Ltd. has shown that the Mount Tom Price ore body lies in the lower part of the Brockman Iron Formation (MacLeod, 1966), and that the concentrations of iron ore are controlled by minor folds near the axis of the Turner syncline. The Brockman Iron Formation has been studied extensively during the investigation of the crocidolite deposits of the Hamersley Range area.

Ryan and Blockley (1965) divided it into five members, the lowermost of which was termed the Dales Gorge Member, consisting of 17 units (macrobands) of banded iron formation (BIF), alternating with 16 macrobands of 'shale' (mixed stilpnomelane, chert, chert-siderite, dolomite, and tuff. Trendall (1965) described the lithology of these rock types, and correlated the 'shales' within the drill core sections available at the Wittenoom Gorge crocidolite mine. He designated the lowest shale band No. 1 and continued the sequence upwards to No. 16. The intervening BIF macrobands were numbered similarly, but as the drill core sections did not penetrate below shale No. 1, the lowermost BIF within the member was not numbered. Ryan and Blockley referred to it as the 'O' BIF, or the Basal BIF.

The type section of the Dales Gorge Member as defined from drill core at Wittenoom Gorge is shown in Figure 9 Column C, and a photographic log of the section has been published by Trendall and Blockley (1968). It has now been established that not only can all 33 macrobands be recognized over the entire outcrop area of the member, but that much of the finer stratigraphic detail visible in the photographic log has the same wide persistence. Thickness variations of the member have also been established over the basin. All 33 macrobands can be counted on the north face of Mount Noname, a prominent bluff 2 miles north of Mount Tom Price, although in the section measured on its south face in 1965, there was a short exposure gap surrounding the 5th and 6th 'shale' units.

The contact between the typical iron formation of the Dales Gorge Member, and the typical shale of the Mount McRae Shale, is gradational, and its definition must therefore be arbitrary. The position chosen for convenience in field mapping is immediately beneath the prominent cliff-forming 'O' BIF. There are however several thinner bands of BIF immediately below this which are here included in the Mount McRae Shale but which some mining companies map as portion of the Brockman Iron Formation. The uppermost of these BIF bands is usually 3 to 4 feet thick and is bounded on both upper and lower sides by one-foot thick shale bands. Where fresh, it con-

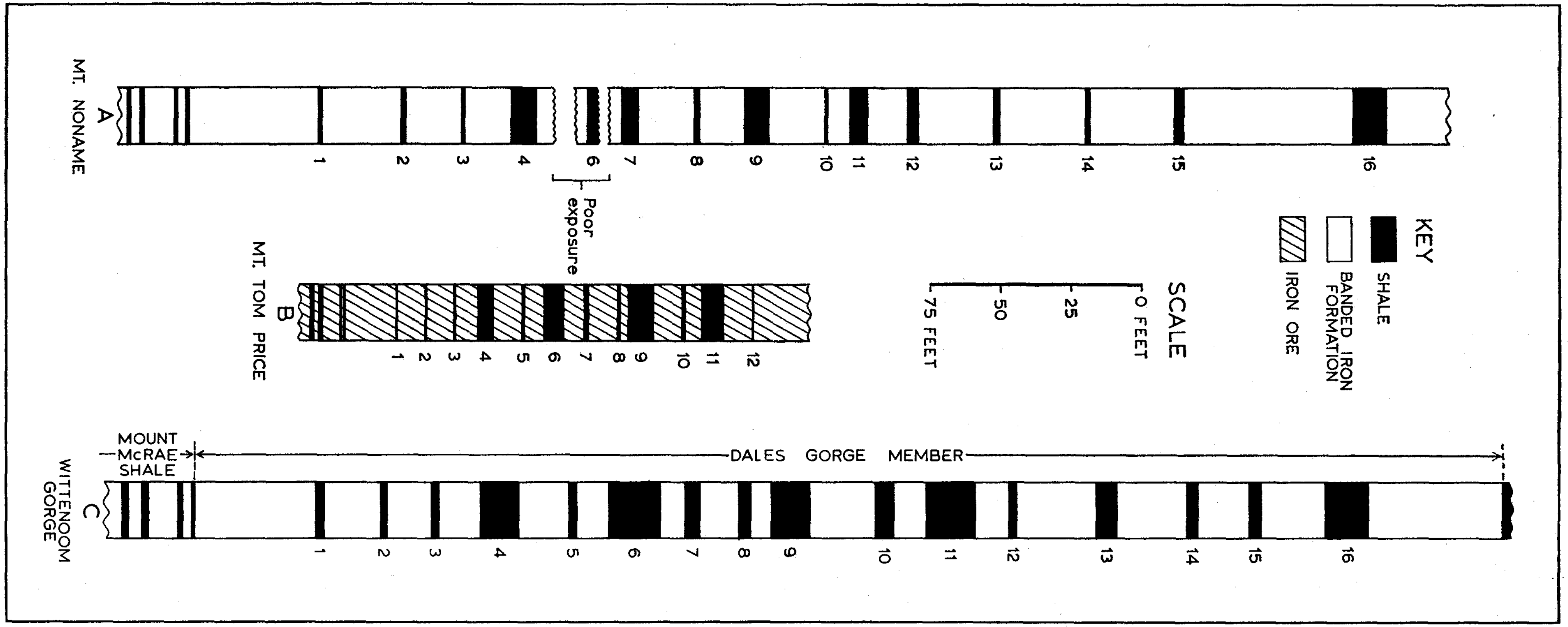

Figure 9. Stratigraphic columns showing relationship between shale bands within the Mt. Tom Price ore body and the shale beds within the upper part of the Mt. McRae Shale and the Dales Gorge Member of the Brockman Iron Formation.

A. Stratigraphic section at Mt. Noname, 2 miles north of Mt. Tom Price.

B. Section of the Mt. Tom Price ore body (from data supplied by Hamersley Iron Pty. Ltd).

C. Type section of Dales Gorge Member as established in diamond drill core at Wittenoom Gorge.

tains a central cherty bed with carbonate blebs which weather out on exposed surfaces to form rows of ovoid pits. The unit has been given the informal name of the 'bed of holes' and has been used as a stratigraphic marker throughout the Hamersley Range area. Another similar band, but without the distinctively pitted bed, occurs a few feet lower in the section.

STRATIGRAPHY OF THE ORE BODY

The Mount Tom Price ore body contains an alternation of bands of hematite, sometimes weathered to goethite, and 'shale', consisting of nondescript mixtures of clay and iron oxides. The shale bands lower the overall grade of the ore, and the thicker bands are mined selectively to prevent their being mixed with the hematite. It is therefore important when designing the position of the benches in the open cut, to know where these thicker bands can be expected. The distribution of shale bands within the ore body has been determined by geologists of Hamersley Iron Ltd from numerous drill core records. A stratigraphic section of the ore body showing this distribution is given in Figure 9B.

From a field study of the textures preserved in the hematite and shale, it was concluded that the hematite derived from original BIF, and that the shale bands in the ore body represent original shale macrobands within the iron formation. The most acceptable scheme of correlation is shown in Figure 9, which compares a section of the ore body (Column B) with sections of the parent iron formation at Mount Noname and Wittenoom Gorge (A & C). Correlative bands within the iron formation and ore body are given the same numbers. The lowermost shale bands have not been numbered, but the suggested correlation is obvious. The correlation is based mainly on the relative spacings and thicknesses of the shale bands, and is supported by other details. For example, shale 4 had a thin band of tuff in both the section at Mount Noname, and in its correlative within the ore body. Again, the 'bed of holes' seems to be reflected in the ore body by distinct pitting within the uppermost, thin hematite band near the base of the section.

APPLICATIONS OF THE SCHEME OF CORRELATION

This correlation between the shales in the ore body and those in the iron formation protore has a number of practical uses. For example, it indicates that the shale bands exposed in the open cut will persist throughout the ore body and are not merely local phenomena. It also suggests that the ratio of hematite to shale in the ore body will increase towards the stratigraphic top.

The most important application of this correlation would seem to be in the study of the origin of iron ore. Here, possibly for the first time, is a chance to compare a column of iron ore with its equivalent section of iron formation protore, and deduce the quantitative chemical and mineralogical changes which have taken place in the transition. To date, these changes seem to be known only qualitatively.

One important aspect of the problem capable of a quick solution is the degree to which the change takes place by replacement of silica in the BIF by iron oxide. Some authors writing on the origin of iron ore advocate a volume-for-volume replacement of the silica by iron oxides, while others incline to the idea that no replacement takes place, but that silica is leached, leaving the iron oxides to be compacted into iron ore. It has also been suggested that a combination of these two processes operated; that is, some leaching and compaction is accompanied by some replacement of silica by iron minerals.

A comparison of columns A and B in Figure 9, shows that approximately 235 feet of BIF between the base of the section and shale 11 are represented by about 118 feet of hematite within the Mount Tom Price ore body. Regional studies of the Dales Gorge Member are sufficiently detailed to rule out stratigraphic thinning as the cause of this change. Therefore, it is certain that the thinning took place during the conversion of BIF to iron ore. Table 1 below compares the chemical analyses of average BIF from the Dales Gorge Member with an average analysis of hematite from Mount Tom Price.

TABLE 1.

Material	Av. BIF[1]		Av. Hematite[2]		Difference (tons)
	Assay (%)	Wt.[3] (tons)	Assay (%)	Wt.[4] (tons)	
Fe	29·9	6·7	67·3	11·1	+4·4
O_2[5]	10·9	2·4	28·7	4·7	+2·3
SiO_2	47·7	10·6	1·6	0·26	—10·3
Al_2O_3	0·5	0·11	1·3	0·22	+ 0·1
Others[6]	11·0	2·5	1·1	0·18	— 2·3
		22·31		16·56	— 5·8

1. Average of 5 analyses of " typical BIF " by Govt Chem. Labs for Geol. Survey of W.A.
2. From MacLeod, 1966, p. 92.
3. Weight of column 235 feet high and one square foot in area.
4. Weight of column 118 feet high and one square foot in area.
5. O_2 contained in FeO and Fe_2O_3.
6. Mainly CO_2, CaO, MgO.

In order to compare the changes quantitatively, the weights of each component in a column one foot square, and equal in height to the equivalent stratigraphic thicknesses of BIF and iron ore (i.e. 235 feet and 118 feet respectively) have been tabulated alongside the percentage compositions.

The figures show that, despite the decrease in volume, the increase in the percentage of iron cannot be accounted for by simple removal of the other components; but there has in fact been an addition of iron to the system. It seems then that the change from BIF to hematite took place partly by leaching of original silica and carbonates with a consequent compaction of the residual iron oxides, and partly by volume for volume replacement of some of the primary constituents of the BIF.

It may be significant that the reduction in volume by 50% is almost exactly equal to the volume of chert bands within the BIF of the Dales Gorge Member. Possibly chert bands within the iron formation are leached completely, resulting in an overall reduction in volume, but silica and carbonate occurring in other bands (e.g. QIO of Trendall, 1965) have been replaced by iron without further reduction in volume. Almost certainly a detailed comparison of sections of the hematite ore with the equivalent stratigraphic sections of the protore BIF, could settle this point, and provide much more information on the genesis of iron ore.

Fresh BIF is available in the diamond drill core at Wittenoom, and the stratigraphic continuity of this over most of the Hamersley Basin has now been established. Good exposures of hematite are seen in the open cut at Mount Tom Price, and presumably there is a considerable amount of drill core available for study. A detailed comparison of the two could throw much light on the physical and chemical processes involved in the transition of BIF to hematite, and perhaps help focus future exploration on the most favourable areas.

A study of the changes that took place in the mineralogy of the shales may indicate the temperature at which the iron ore formed and could assist in establishing the geological environment. This could be of great importance now that palaeomagnetic work on the hematite has indicated a Middle Precambrian time for its origin (Porath, 1967) suggesting that the major hematite ore bodies in the Hamersley Range area may have a deep-seated origin, and not be due to the Tertiary weathering which formed the more widespread, but lower grade crust-ore hematite deposits.

It is hoped that some organization will take advantage of this unique opportunity to make a significant scientific, and possibly profitable, contribution to the study of the origin of iron ore.

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RANGE COPPER-LEAD DEPOSITS, ASHBURTON GOLDFIELD

by J. G. Blockley

INTRODUCTION

Since 1962, two small copper-lead mines have been discovered and worked in an area of metamorphic rocks 3 to 4 miles north of Range Station homestead in the western part of the Ashburton Goldfield. Known as the Turtle and the Range, the mines are about 20 miles distant from any previously recorded deposit of base metals, and thus may be considered to form a new locality.

Range Station is reached from the re-routed North-West Coastal Highway by a track branching westwards 18 miles north of Nanutarra, and is about 60 miles by road from the port of Onslow. The locality plan on Plate 21 shows the positions of the mines with respect to the homestead. At the time of inspection, neither mine was being worked, although the Range lead mine seemed only temporarily abandoned.

The Turtle mine was worked in 1962 by J. Heinsen, and produced a reported 45.14 tons of ore averaging 4.43% copper. Although lead was present in the ore, no assays for this metal were made at the time. Due to its low grade, the ore was not readily marketable, and production ceased. In 1964, Westfield Minerals N.L. obtained an option over the property and drilled 18 blast-holes to test the size and grade of the lode. The company relinquished the option when results proved disappointing.

The Range lead mine was pegged first in 1967 and worked during 1968 by K. Stubbs and party. To date no production figures have been lodged with the Department but at the time of inspection some 20 to 25 tons of high-grade ore were at grass.

PREVIOUS INVESTIGATONS

No published account of the geology of the two mines exists, but a private report for Westfield Minerals has been drawn upon for information concerning that company's drilling results. The broad geological features of the area of the deposits are shown on the State Geological Map and on Plate 2 of Condon (1965).

GEOLOGY

In the area around the mines, the bed-rock geology is largely obscured by sand. The few natural exposures present are quartz reefs on fault lines. The bed-rock exposed in pits and costeans is chloritic and micaceous schist, probably a metamorphosed equivalent of the Lower Proterozoic Wyloo Group. Granite stocks intrude the metamorphic rocks a few miles southwest, and also a mile north of the deposits. The lodes worked in the two mines are in quartz veins or stockworks striking at 060 to 070 degrees across the northwesterly trend of the metamorphic banding. The Turtle mine is close to a large north-northeasterly fault marked by a prominent quartz reef.

TURTLE MINE

The Turtle mine is on a low, elongated hummock rising 20 or 30 feet above the surrounding sandplain. Lead and copper minerals are disseminated through lodes of ferruginous quartz forming lenses within a silicious stock work made up of silicified schists and many closely spaced quartz veins. The stockwork extends over a length of 700 feet and has a maximum width of 100 feet. Most of the lenses of lode matter are at the northeastern end of the stockwork, although a few patches of ferruginous quartz with traces of lead and copper occur elsewhere. Plate 21 shows the distribution of the lodes within the stockwork. The lodes that have been tested dip steeply to the east.

The largest lode is 160 feet long and averages 12 feet in width. It contains lead and copper throughout, but is richest at its northern end where a section 8 to 10 feet wide was mined from an open cut 10 feet deep. Twenty feet east of this lode is another 1 to 3 feet wide and about 90 feet long. A shaft 27 feet deep was sunk near the northern end of this lode where it is widest and richest, but elsewhere it has been tested only by shallow pits. The other lodes are all small and appear to be low in grade. Ore minerals present are cerussite, cuprite, and malachite; and galena was reported from one of the drillholes.

Of the 18 holes drilled by Westfield Minerals N.L., only two intersected lodes of possible ore grade. Hole 15, drilled beneath the open cut, encountered 40 feet of lode (true width) averaging 4.6 per cent lead and 3.9 oz. of silver to the ton. A section in the middle of the lode contained 3.7 per cent copper over a true width of 8 feet. Hole 3, drilled from a position 50 feet southwest of the shaft, cut 10 feet of lode (true width) assaying 2.45 per cent lead. Two narrow sections within this each contained 11 per cent copper.

Of two samples taken by the writer, the first from the face of the open cut assayed 6.81 per cent lead, 0.02 per cent zinc, 3.39 per cent copper and 160 p.p.m. silver, and the second from the lode worked in the shaft, assayed 4.10 per cent lead, 0.70 per cent copper and 100 p.p.m. silver.

RANGE MINE

The lode worked in the Range mine follows a silicified shear-zone cropping out intermittently through a cover of sand and has been traced by costeaning over a distance of 1,300 feet. Mining has been restricted to a shoot about 250 feet long, some 300 feet from the eastern end of the line. The lode here is from 2 to 5 feet wide, dips 80°S, and consists of dense, greyish quartz carrying finely disseminated pyrite, chalcopyrite, and galena. Most of the ore mined has come from veins or lenses up to one foot wide, of massive, fine-grained galena situated on the hanging-wall side of the lode. Oxidation has affected the lode only near the surface where the economic minerals are malachite and cerrussite.

At the time of inspection, workings comprised a number of pits and bulldozed costeans, a shallow open cut 75 feet long, and 4 shafts with depths ranging from 10 feet to 30 feet. In the deepest shaft, the lode was 3 ft 3 in. wide, including a vein of massive galena 11 inches wide at the hanging wall. Seventy feet further west in a shaft 25 feet deep, the lode widens to about 5 feet on a roll in the shear. Again it is richest on the hanging-wall side and a little gouging has been carried out from the shaft in this zone. The most recent work on the mine has been directed towards the sinking of a new shaft near the western end of the ore shoot, and at the time of inspection, this was 10 feet deep. The results of 3 samples taken from the lode are as follows:

No.	Position	Width	Pb per cent	Zn per cent	Ag p.p.m.
16358	Ore dump	....	35·5	0·09	130
16359	30 ft shaft	3′3″	32·5	0·03	130
16361	25 ft shaft	Abt 4 ft	15·5	0·33	100

CONCLUSIONS

Both the Range and Turtle mines are small deposits hindered from becoming profitable producers by their distance from ore treatment facilities and markets.

The lead content of the Turtle mine is too low to be worth extracting, but would probably prevent the ore being accepted as cupreous additive to fertilizer. One feasible method of winning the copper from the lodes is by leaching with sulphuric acid. The largest lode should be capable of yielding several thousand tons of ore by open-cut mining, and although some crushing might be required to render the copper accessible to the acid, the lode material should be free of acid-killing carbonates. Further testing would be needed before the economics of such a venture could be assessed.

At present, only the high-grade veins of massive galena within the lode of the Range mine can be exploited. In order to win all the lead in the lode, a small crushing and concentrating plant would be required. Ore in sight at present is insufficient to justify the cost of such a plant, but more thorough testing and development could change this situation.

The extensive sandplain surrounding the deposits may well conceal other lodes and further prospecting using the techniques of geophysics and geochemistry seems warranted.

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THE GEOLOGY OF THE GRANITIC ROCKS OF THE POONA–DALGARANGA AREA, MURCHISON AND YALGOO GOLDFIELDS

by P. C. Muhling

ABSTRACT

The Archaean granitic rocks of the Poona-Dalgaranga area have been divided into two groups. A border facies and an internal facies have been recognized, each containing several textural units. The border facies forms a closure of granitic rocks elongated parallel to the regional tectonic structure and encircling the internal facies. These granitic rocks are in a recess in the metamorphic rocks at the eastern margin of a batholith delineated by Johnson (1950).

There are two types of mineralization directly related to the granites. One comprises pegmatites with beryl, emeralds, cassiterite, tapiolite and tantalite; while wolframite and molybdenite deposits form the second type. Prospecting for these minerals should be concentrated in the metamorphic rocks at the edge of the granite. The probability of occurrence of alluvial tin deposits is not yet known.

INTRODUCTION

The Poona-Dalgaranga area is part of the western half of the Cue 1:250,000 sheet area (SG/50-15) and is enclosed between latitude 27°00′ to 28°00′S and longitude 117°00′ to 117°45′E. The locality is shown in Plate 22. Poona is in the north of the area, about 35 air miles northwest of Cue (about 42 miles by graded road). Dalgaranga homestead near the southern limit of the area is about 45 air miles north-northeast of Yalgoo.

In this report all granitoid rocks are referred to as 'granites' or granitic rocks. The ratio of plagioclase feldspar to K-feldspar has been determined in some rocks but not in all.

The first geologists in the area investigated the mining centres, but gave little attention to the granitic rocks. H. P. Woodward (1914) and L. de la Hunty (1962), have examined different aspects of the geology of this area.

In 1966, mapping of the Cue 1:250,000 sheet area was commenced as part of a regional mapping programme in the Murchison and Yalgoo Goldfields. Particular attention was given to the mineralized pegmatites of the Poona-Dalgaranga area. The different types of 'granites' near the mining centres were mapped and a study was made of igneous flow structures, and of the attitudes of pegmatites and joints, to determine the shape of the intrusions. Other information sought was the level of intrusion of the 'granites', the level within the 'granites' that erosion had reached, and the sequence of intrusion, metamorphism and folding. From the 'granite' study it was hoped to estimate the possibility of the occurrence of pegmatite minerals in primary and alluvial deposits. Another aim was to determine whether there was a pattern in the distribution of these deposits and a control for this pattern.

STRUCTURE

Three structural trends were recognized in the area:

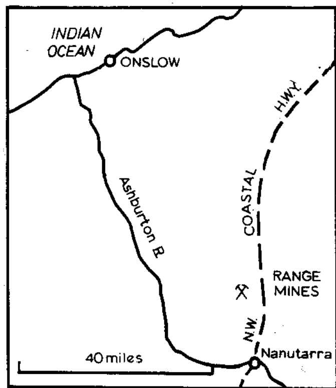
(1) the Weld Range trends east-northeast.

(2) From Poona around the eastern and southend edge of the intrusion to Kylie, the country rocks are folded about axes trending north and northeast.

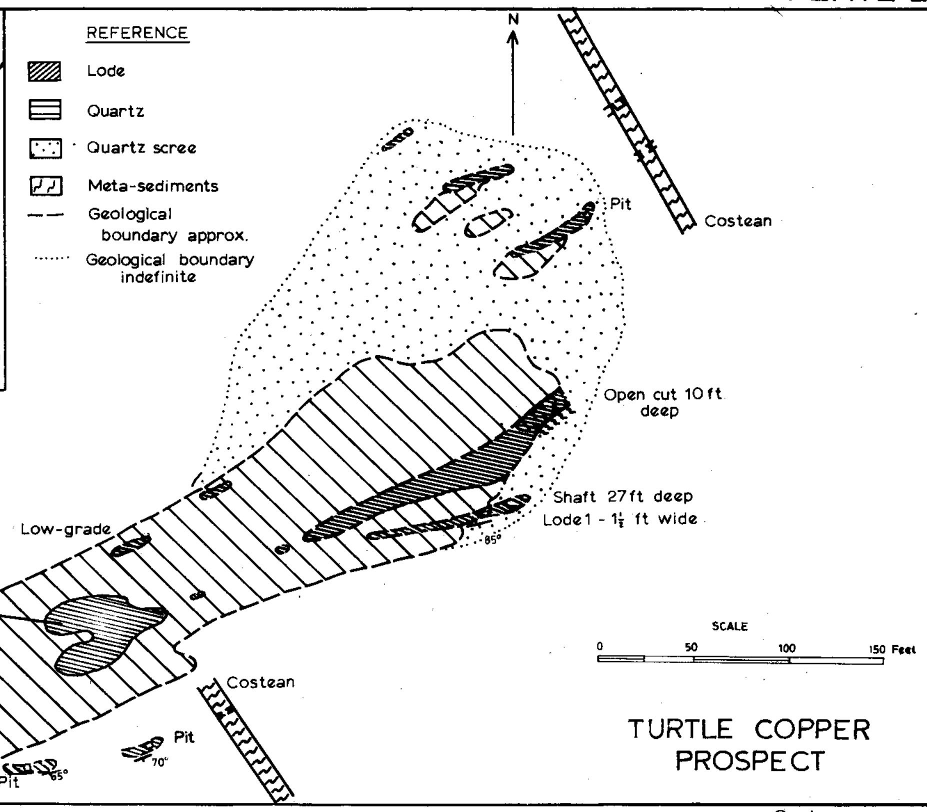
(3) The country rocks and 'granites' southeast of Dalgaranga homestead, and granites in the northwest part of the area, trend at 160°.

The types of foliations in 'granites' are represented on the map. One is a primary igneous foliation shown by aligned feldspar laths, small inclusions of country rock, and schlieren. The second foliation is of biotite grains and distorted quartz grains. Its origin is uncertain but it occurs in 'granites' next to country rock. This foliation was caused by shear in a solid crust of 'granite' near country rock during final stages of consolidation, or shear associated with folding; or possibly by primary igneous flow (partly protoclastic).

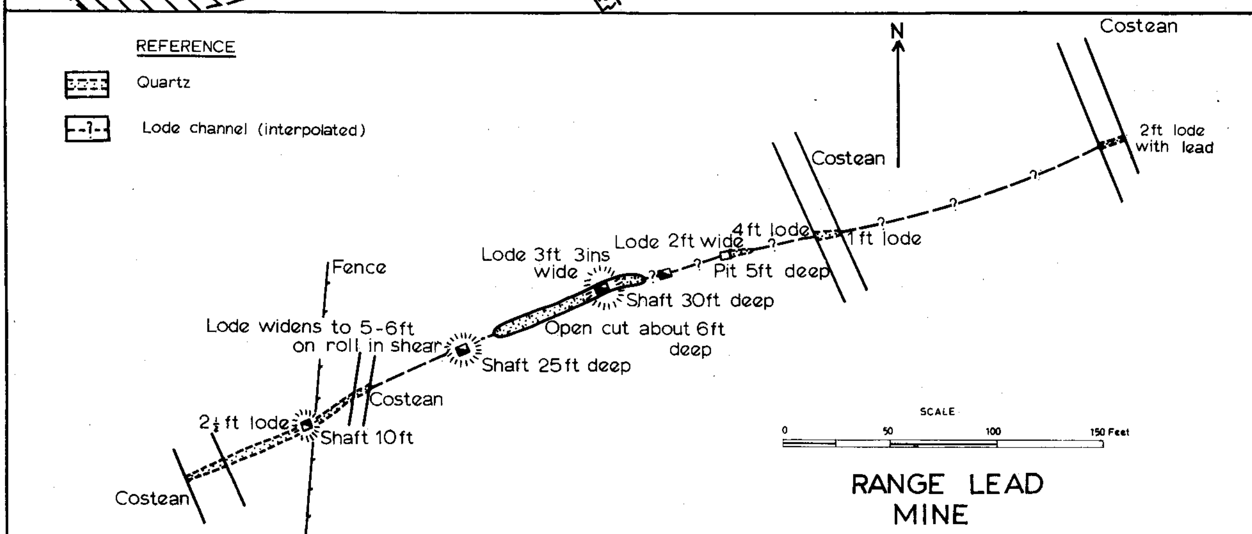
The primary foliations in the 'granites' appear to be controlled by the shape of individual intrusions which in turn form a pattern suggestive of an elliptical batholith. The long axis of the intrusion trends north-northeast, parallel to the regional



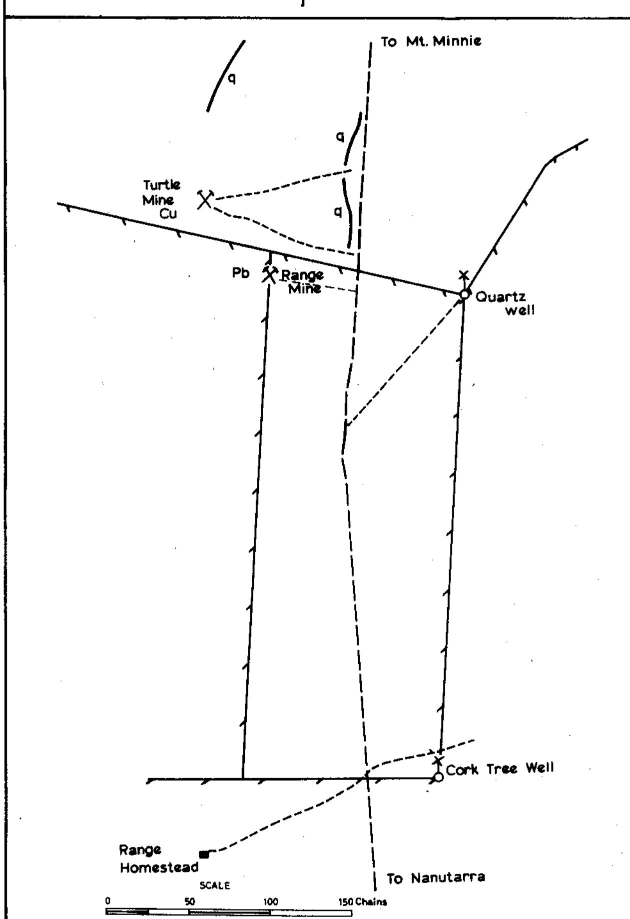
LOCALITY MAP



TURTLE COPPER PROSPECT



RANGE LEAD MINE



LOCALITY PLAN

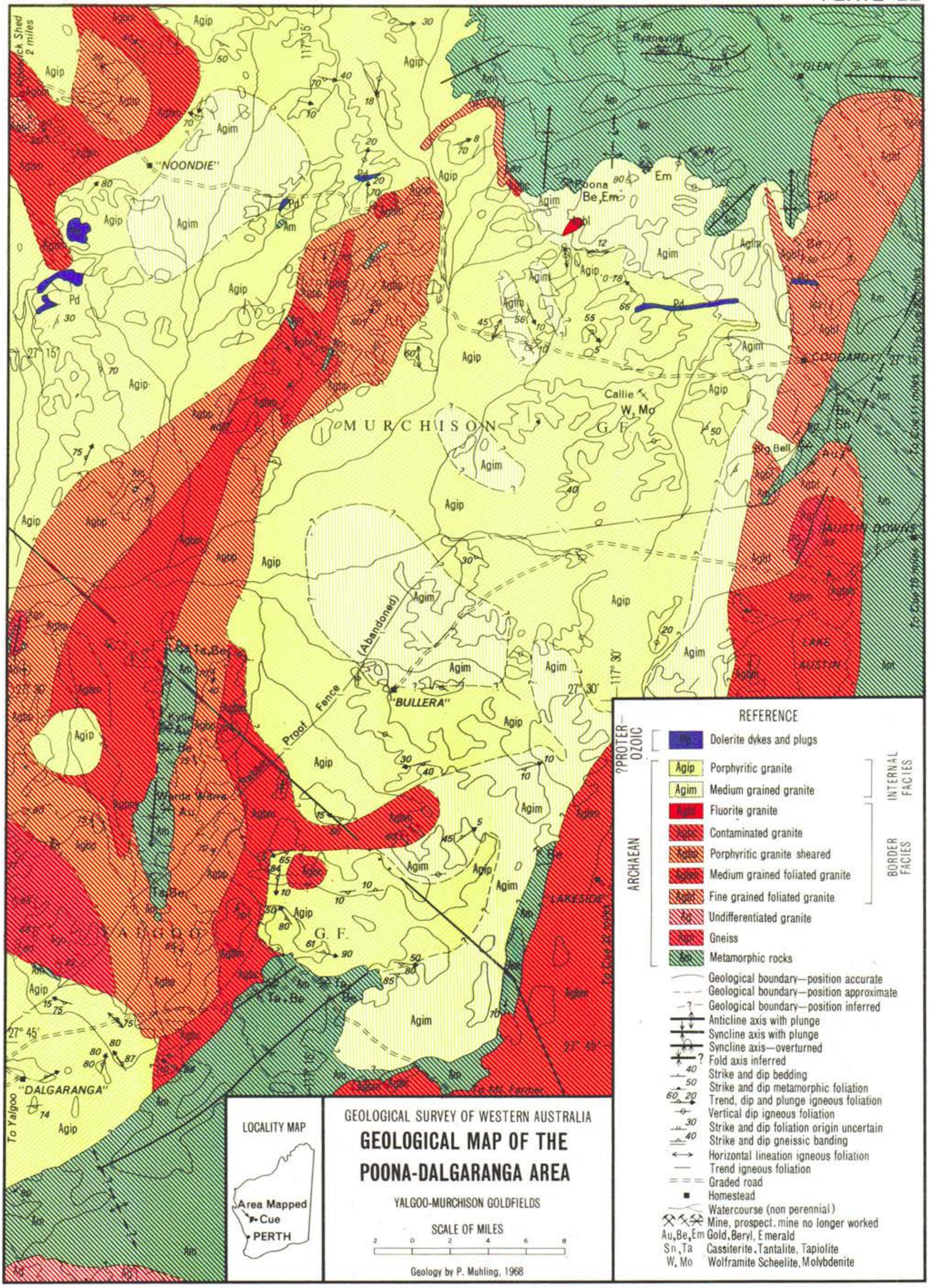
SURFACE PLANS OF RANGE AND TURTLE MINES

Ashburton Goldfield

Western Australia

To accompany report by J.G. Blockley 1968.

PLATE 22


GEOLOGICAL SURVEY OF WESTERN AUSTRALIA
GEOLOGICAL MAP OF THE
POONA-DALGARANGA AREA
YALGOO-MURCHISON GOLDFIELDS
SCALE OF MILES
Geology by P. Muhling, 1968
LOCALITY MAP
Area Mapped
Cue
PERTH
REFERENCE
?PROTEROZOIC
ARCHAEAN
Pd Dolerite dykes and plugs
Agip Porphyritic granite
Agim Medium grained granite
INTERNAL FACIES
Agfl Fluorite granite
Agbc Contaminated granite
Agbp Porphyritic granite sheared
Agbm Medium grained foliated granite
Agbf Fine grained foliated granite
BORDER FACIES
Ag Undifferentiated granite
Agn Gneiss
Am Metamorphic rocks
Geological boundary—position accurate
Geological boundary—position approximate
Geological boundary—position inferred
Anticline axis with plunge
Syncline axis with plunge
Syncline axis—overturned
Fold axis inferred
Strike and dip bedding
Strike and dip metamorphic foliation
Trend, dip and plunge igneous foliation
Vertical dip igneous foliation
Strike and dip foliation origin uncertain
Strike and dip gneissic banding
Horizontal lineation igneous foliation
Trend igneous foliation
Graded road
Homestead
Watercourse (non perennial)
Mine, prospect, mine no longer worked
Au, Be, Em Gold, Beryl, Emerald
Sn, Ta Cassiterite, Tantalite, Tapiolite
W, Mo Wolframite Scheelite, Molybdenite
MURCHISON G.F.
YALGOO G.F.
"NOONDIE"
"BULLERA"
"DALGARANGA"
"GLEN"
GOODARDY
AUSTIN DOWNS
LAKE AUSTIN
LAKESIDE
Poona
Callie
Big Bell
Rabbit Proof Fence (Abandoned)
To Yalgoo
To Mt. Farmer
27° 15'
27° 30'
27° 45'
117° 15'
117° 30'

strike of metamorphic rocks in the Cue sheet area. Hence the shape and the intrusion of the 'granites' are closely linked with regional tectonic structure.

The sequence of events seems to have been:

(1) Folding and metamorphism of country rock. The relation between these two processes has not yet been determined.

(2) Intrusion of 'granite' synchonous with folding, though most granite was intruded after folding of the country rocks.

(3) metasomatism of country rocks at the contact with the 'granites', producing quartz-feldspar-biotite rocks.

DESCRIPTION OF 'GRANITE' UNITS

The 'granites' have been subdivided according to their textures and structures. There are gradations between different textural types and the distinction between units at some places is arbitrary. Some areas have more than one 'granite' and the mixture has been classified under the dominant type. Many boundaries between different 'granites' are mixed zones ranging in width from a few yards to about a mile.

All the 'granites' contain quartz, two feldspars (K-feldspar and a plagioclase feldspar) and biotite. There are small areas of muscovite 'granite' near Poona but the boundaries have not been mapped.

Preliminary work on thin-sections shows that the medium-grained granite, porphyritic granite, and sheared porphyritic granite all have less plagioclase than K-feldspar. These are true granites and the phenocrysts are microcline.

The 'granites' can be separated into two categories—a border facies and an internal facies.

BORDER FACIES

Fine-grained foliated 'granite' (Agbf)

The fine-grained foliated 'granite' is usually conformable with the country rock, though locally it has intruded the country rock. Most of the 'granite' is foliated, although there is some gradation into a massive type. The pattern of the foliation suggests they are primary. Numerous xenoliths of country rock are present.

Medium-grained foliated 'granite' (Agbm)

Rounded boulders, elongated parallel to the foliation are a common feature of the medium-grained foliated 'granite'. Its colour varies from light grey to white and there are some streaks of biotite.

Two, and occasionally three foliations can be detected in this 'granite'. No conclusions about the origin of these foliations can be presented until more work has been done.

This unit is intrusive into the contaminated 'granite'.

Contaminated 'granite' (tonalite) (Agbc)

There are two varieties of contaminated 'granite' but they are not distinguished from each other on the map.

The first variety crops out as rounded, grey tors and contains xenoliths of quartz and biotite lenses. This rock has not been examined in thin-section but it is probably a tonalite.

The other variety has numerous lenses and flakes of biotite set in a pale pink, medium-grained groundmass. There may be feldspar phenocrysts present. At most places this rock has two foliations defined by biotite flakes—one parallel, the other perpendicular to, the contact with the country rock. It is probably a border facies of the porphyritic granite.

Sheared porphyritic granite (Agbp)

The sheared porphyritic granite intrudes the country rock and the medium-grained foliated 'granite'. The foliation is shown by distorted feldspar phenocrysts (many have a square shape) and lenticles of quartz in the groundmass. The intensity of foliation varies.

This unit is generally mixed with the medium-grained foliated 'granite' and it is not known whether these two types can be separated into mappable units everywhere. Where the two types are mixed, their foliations are approximately parallel.

The boundary between this granite and the porphyritic granite is arbitrary (determined by the detection of signs of shear).

Fluorite 'granite' (Agbl)

The main exposure of fluorite 'granite' is about 3 miles south of Poona mine. It is medium-grained with scattered spots of fluorite and has a characteristic airphotograph pattern caused by closely-spaced joints.

INTERNAL FACIES

Medium-grained granite (Agim)

Medium-grained granite has intruded the fine-grained, foliated 'granite.' Some margins are porphyritic and grade into an even-grained rock. Part of the unit has a primary foliation of schlieren and feldspar crystals. The remainder of the granite is massive.

Porphyritic granite (Agip)

The porphyritic granite has a characteristic outcrop pattern of domes and rounded boulders.

It is a pale pink, medium to coarse-grained granite with phenocrysts ranging in length from ½ inch to 5 inches. The primary foliation is generally parallel to the contacts with other rock types. This granite appears to have intruded all other types though much of the evidence from contacts with medium-grained granites is inconclusive.

Gneiss (Agn)

Gneiss is a general term and is used only in a textural sense since it is uncertain whether these are metamorphic rocks.

Parallel lenses of metamorphosed country rock up to 3 feet wide are set in a medium-grained foliated granitic rock with discontinuous streaks of biotite less than an inch wide. This unit seems to be folded and has been intruded by medium-grained foliated 'granite'.

COUNTRY ROCKS

The layered succession has been metamorphosed. It consists dominantly of fine-grained, basic, igneous rocks with intrusive gabbros and pyroxenites (tremolite schist). Banded iron formation, fine-grained acid volcanic rocks with intrusive porphyries and minor fine-grained sediments, form the remainder of the country rocks.

ECONOMIC GEOLOGY

Mineralized pegmatites have been worked at Poona, near Big Bell, near Dalgaranga, west of Lakeside, and north and south of Kylie. The main minerals sought were beryl, emerald, tapiolite, tantalite, and cassiterite.

The pegmatites seem to be late stage differentiates of the 'granites'. All of the mineralized pegmatites are in the country rock adjacent to 'granite' but the 'granite' is different for each mining locality.

At Poona the pegmatities strike about 90° and dip 80° south; pegmatites near Big Bell are also oblique to the country rock and trend 70°; most of the pegmatities at other localities parallel the foliation of the host rock.

Other minerals associated with the 'granite', such as wolframite, scheelite and molybdenite, have been mined from quartz veins associated with late stage differentiates of granite near Callie Soak. It is significant that this occurrence is near the centre of a closure defined by flow structures in the porphyritic granite, and is comparatively close to the contact of the granite with the country rock. Wolframite has been mined from a quartz vein intrusive into metamorphosed fine-grained basic rocks, about 7 miles east from Poona.

CONCLUSIONS

The age of the 'granites' is unknown but is probably Archaean and possibly close to lower Proterozoic.

The association of a foliation which occurs in border facies 'granites' with a concentration of xenoliths suggest that the granitic rocks between Kylie and a point about 8 miles west of Poona could be regarded as the western boundary of all 'granites' further east. This indicates that an area of 'granites' forms a structural unit within the batholith defined by Johnson (1950). These 'granites' are probably of the same age as the batholith. The large area of 'granites' belonging to the border facies compared with those of the internal facies suggests the level of erosion is not far below the original roof of the intrusion. On a regional scale the granitic rocks of the Poona-Dalgaranga area can be regarded as an intrusion near the edge of the batholith.

Any mineralized zones in the top of the 'granite' have probably been eroded, though there are remnants of high temperature mineralization near Callie Soak. Because of the removal of the roof of country rock from the intrusion, and the distribution of mineralization, future prospecting for primary deposits should be concentrated in the metamorphic rocks around the edges of the 'granite'.

The presence of primary mineralization indicates that alluvial deposits may have formed, but more work is necessary in the Quaternary and Tertiary sequences before the degree of probability of their formation can be assessed.

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DASYCLADACEAN ALGAE FROM THE WERILLUP FORMATION, ESPERANCE

by A. E. Cockbain

ABSTRACT

The dasycladacean algae *Neomeris* and *Larvaria* are recorded from Australia, for the first time, in the Upper Eocene Werillup Formation. Present day *Neomeris* is a tropical (minimum temperature 20°C) and shallow water (less than 10m depth) genus and this suggests similar conditions existed in the Esperance area during the Upper Eocene. A tentative position for the Upper Eocene 20°C isocryme in the Australian region is plotted on a map.

INTRODUCTION

In the area east of Esperance, the Werillup Formation of the Plantagenet Group does not crop out and is known only from several boreholes drilled for water. Two boreholes in particular, Neridup 20 on Neridup Location 169 and Brookman 1 on Neridup Location 118 (see Figure 10) have yielded interesting fossil assemblages from this formation. In Neridup 20, yellow silty sandstone overlies dark-grey siltstone and sandstone. From the dark-coloured sandstones Cockbain (1967) recorded the larger foraminifer *Asterocyclina* together with an Upper Eocene fauna of smaller foraminifers. Brookman 1 borehole passed through a similar stratigraphical section. A sample from 85 to 94 feet (G.S.W.A Palaeontology Collection F7784) contains an abundant fauna of foraminifers, ostracods, molluscs, and bryozoans. The foraminifers include *Maslinella chapmani*, *Bolivinella* sp., *Notorotalia crassimura*, *Operculina* sp., and *Elphidium* sp. and suggest an Upper Eocene age. Figure 11 shows the correlation between this borehole and Neridup 20. In addition the dasycladacean algae mentioned below are also present in sample F7784.

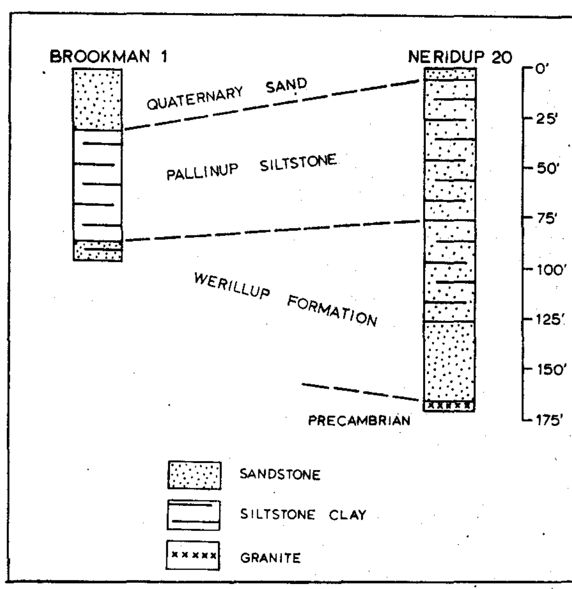


Figure 11. Correlation of Brookman 1 and Neridup 20 boreholes.

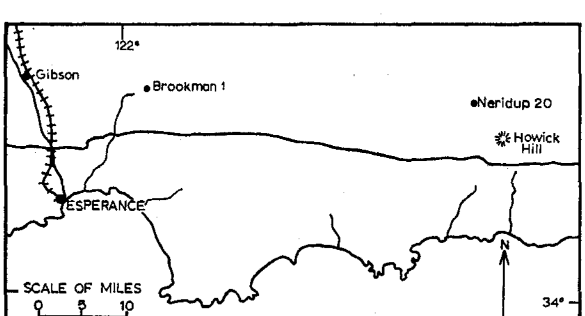
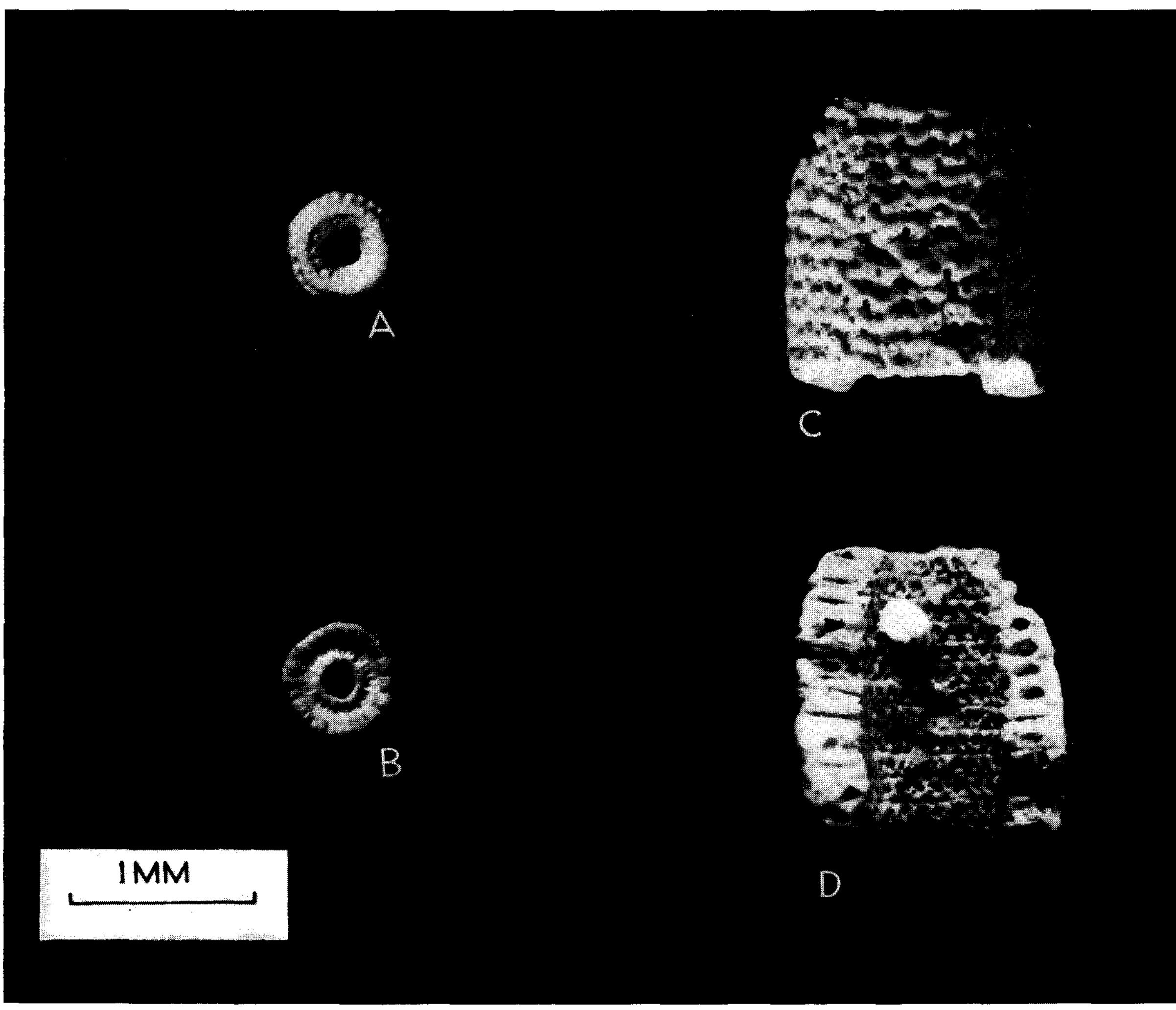


Figure 10. Map showing location of Brookman 1 and Neridup 20 boreholes.

SYSTEMATIC PALAEONTOLOGY

Dasycladacean algae have not been recorded previously from the Australian Tertiary. Like all fossil dasycladaceans the material is preserved as calcareous external moulds of the branches around the central stem of the original thallus. The fossils can be easily extracted from the rock matrix

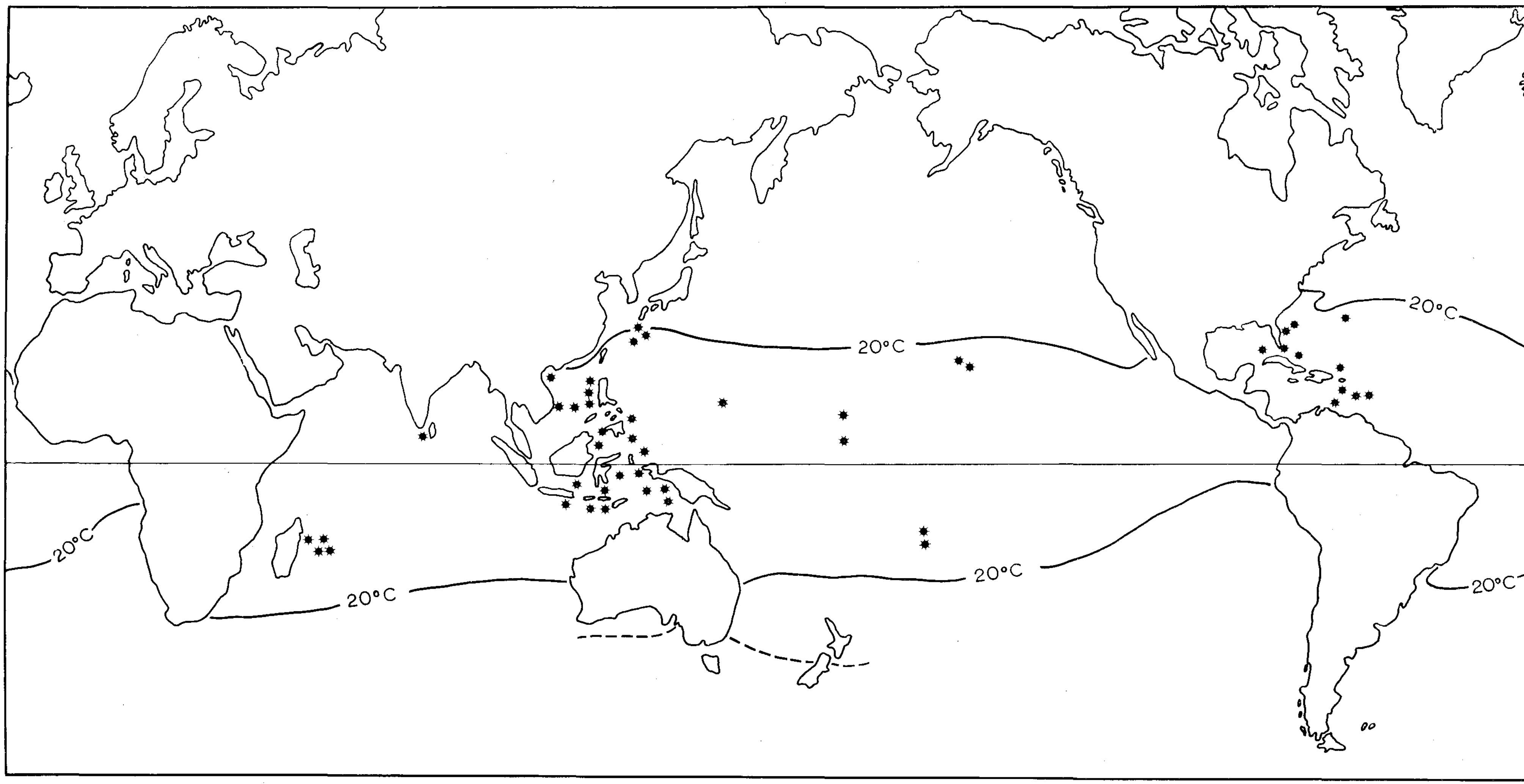
PLATE 23



Larvaria sp. (A) upper and (B) lower views of one segment of cylindrical external mould of thallus (G.S.W.A. F7784.1).

Neomeris sp. (C) external (D) internal views of broken portion of cylindrical external mould of thallus (G.S.W.A. F7784.2).

PLATE 24



Distribution of recent species of *Neomeris* (✱) in relationship to 20°C isocryme (after Konishi and Epis, 1962) and tentative position of Upper Eocene 20°C isocryme.

and may be examined whole. Two genera are present; no attempt is made to describe the fossils in this report.

Phylum CHLOROPHYTA
Class CHLOROPHYCEAE
Order DASYCLADALES
Family DASYCLADACEAE
Tribe NEOMEREAE

Neomeris sp.

Plate 23, C, D

Remarks: Johnson (1961) gives the stratigraphic range of the genus as Cretaceous to Recent, with a world-wide distribution.

Larvaria sp.

Plate 23, A, B

Remarks: Cretaceous to Oligocene, with greatest development in Middle Eocene. The genus has been recorded previously in Europe and North America (Johnson, 1961).

DISCUSSION

The genus *Neomeris* is still living and Konishi and Epis (1962) have summarised data on the geographical distribution and depth range of recent species.

The accompanying map (Plate 24) shows the distribution of Recent *Neomeris*. The genus is tropical and occurs in both the Caribbean and the Indo-Pacific regions. At the present time it does not live where the mean temperature of the coldest month falls below 20°C. Assuming that Eocene species were similar in their temperature tolerance, this suggests that the sea in the Esperance region was tropical in Upper Eocene times. A similar conclusion was drawn on the evidence of *Asterocyclina* in the nearby Neridup 20 borehole (Cockbain, 1967). The additional algal evidence permits a refinement in that there was probably a southern shift of the 20°C isocryme of at least 600 miles in the Upper Eocene.

Devereaux (1967, fig. 1) has shown, from isotope work, that the Upper Eocene temperature at the latitude of Wellington was just over 20°C and he comments that the surface water temperature may have been one or two degrees higher. Whilst the Western Australian and New Zealand figures are not strictly comparable, they do suggest that in the Upper Eocene, the 20°C isocryme lay well to the south of its present position. On the other hand, palaeotemperature data from Victoria (see Dorman, 1968, for references) indicate no warming of the sea in the Eocene; in fact the Upper Eocene temperature there was about 15°C according to Dorman (1968, fig. 5). Bearing these facts in mind a tentative position for the Upper Eocene 20°C isocryme is shown on the map (Plate 24). At present no reason can be given for the northward swing of this isotherm in eastern Australia.

By contrast, Darlington (1965) believes that the climate in southern Australia and New Zealand was never fully tropical at any time during the Tertiary. In part this conclusion is based on the diversity of *Nothofagus* in southern Australia (see Darlington, 1965, p.96). However *Nothofagus* of the *N. brassi* group is known from lignites in the Werrillup Formation near Albany (B. S. Ingram, personal communication Nov. 1968). The *N. brassi* group is found nowadays only on mountains in New Guinea and New Caledonia. In New Guinea the trees are associated with " . . . a rich fauna of Carabidea (beetles) . . . almost all of them . . . derived from the surrounding tropical lowlands" (Darlington, 1965, p 31). Hence this particular group of *Nothofagus* seems to be capable of living, under suitable conditions, in a tropical climate.

Konishi and Epis' (1962) data on the depth range of *Neomeris* show that the genus presently lives between 0 and 10 metres. Johnson (1961) states that the Family Dasycladaceae as a whole normally occurs between low tide mark and 10 or 12 metres, with the greatest development near low tide level. Hence the Werillup Formation in Brookman 1 borehole was probably laid down in very shallow water, with the maximum depth around 10 metres. This is borne out by the presence in the formation of strongly ornamented, robust species of foraminifers and by the occurrence of numerous shell fragments.

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THE JOFFRE MEMBER IN THE GORGES SOUTH OF WITTENOOM

by A. F. Trendall

ABSTRACT

The Brockman Iron Formation is one of eight constituent formations of the Precambrian (2,000 m.y. old) Hamersley Group, of the Hamersley Range area in the northwestern part of Western Australia. Its members, from the base upwards, are: Dales Gorge Member (iron formation), Whale back Shale Member, Joffre Member (iron formation), and Yandicoogina Shale Member. The Joffre Member, at about 1,200 feet, is the thickest of these, but has received less attention than the Dales Gorge Member because of its relatively uniform lithology and low economic interest. In an area about 10 miles south-southwest of Wittenoom (lat. 22° 15′ S, long. 118° 20′ E), Joffre Creek flows for three miles through deeply incised gorges in which the gently dipping Joffre Member is spectacularly exposed. Measurement of the lower 900 feet provides a section on which the positions of 75 minor stratigraphic breaks (69 stilpnomelane-rich shales, 5 porcelanites and a limestone) appear. All these are thin and few conspicuous, but gross variations in the stratification, and the grouping of the four lower porcelanites, may have practical use in lithostratigraphic correlation. The position of the base of the Joffre Member is shown, locations within it of previously published data are given, and advice on access is given, so that the paper can be used as a practical field guide.

INTRODUCTION

The Precambrian (about 2,000 m.y.) Hamersley Group was first defined in the Hamersley Range area of Western Australia by MacLeod and others (1963), with a thickness of about 8,000 feet. Among its eight constituent formations, which they also defined, was the Brockman Iron Formation, about 2,200 feet thick. It is one of the best preserved and most extensive Precambrian iron formations now in existence. Ryan and Blockley (1965) divided this formation into five members, but Trendall and Blockley (in press) discarded the uppermost of these. Of the four members currently recognized the lowermost, the Dales Gorge Member, is distinguished by 33 easily recognizable subdivisions (macrobands) which make it the most suitable for detailed stratigraphic study; by a fortunate coincidence it is also the principal host rock for both crocidolite and iron ore in the Hamersley Range area. Trendall and Blockley (1968) published a complete photographic record of the 466.25-foot type section of the Dales Gorge Member which they redefined in drill core from the Wittenoom—Yampire area. Trendall (1966) had already given a detailed description of some features of the lower part of the member in a paper which serves as a field guide to the outstanding exposures at Dales Gorge itself.

The Dales Gorge Member is succeeded upwards by the Whaleback Shale Member, about 200 feet thick. Above this lies the Joffre Member (originally called the Mindy Mindy Member by Ryan and Blockley, 1965), of which a type section measured at Yandicoogina Creek has a thickness of 1,145 feet; the uppermost of the four members, the Yandicoogina Shale Member, immediately overlies the Joffre Member. In contrast with the Dales Gorge Member, with its strong economic interest. and easy stratigraphic subdivisibility, there is little evident lithological variation within the iron formation of the Joffre Member, and only recently has it been discovered to be associated with saleable iron ore. Trendall and Blockley (in press) in a full report on several years of work on all the iron formations of the Hamersley Group, fully described the distinctive lithological and other features of the Joffre Member from observations over a wide area, including the gorges downstream from Joffre Falls, south of Wittenoom. In these gorges, for just over 3 miles between Joffre Falls and the head of Wittenoom Gorge, Joffre Creek flows, largely by way of a sequence of permanent pools, between steep joint-controlled cliffs of the Joffre Member, to give much spectacular exposure of high quality. However, the main stratigraphic concern of Trendall and Blockley (in press) was with the Dales Gorge Member, and they did not systematically measure the section exposed there to determine the exact stratigraphic levels of their observations.

This measurement was carried out in August 1968. The main purposes of this paper are to record the minor lithological variations present in this measured section, to compare the reported discontinuities with those of the type section measured at Yandicoogina Creek, to indicate the positions within the Joffre Member of data already published or in press, and to record the exact equivalence between the base of the member exposed in the gorge and the correlative drill core in the collection of the Geological Survey of Western Australia from Hole 47A, which is the upward continuation of the designated type section of the Dales Gorge Member (Trendall and Blockley, 1968). Sufficient details of access and structure are included for this paper to be used as a practical field guide for independent inspection of the Joffre Member in these gorges.

LOCATION, ACCESS, MORPHOLOGY, AND NOMENCLATURE OF THE GORGES

The gorges with which this paper is concerned occupy an area centred about 10 miles south-southwest of Wittenoom township (lat. 22° 15′ S, long. 118° 20′ E) in the northwestern part of Western Australia. Plate 25 is a map of this area; its location may be identified on the 1 : 250,000 scale map of de la Hunty (1965). The mouth of Wittenoom Gorge lies just south of the township and a sealed road follows the broad floor of the gorge southwards for about 5 miles to the old Wittenoom and Colonial crocidolite mines and their associated service buildings. The road follows Joffre Creek closely; the creek flows only after rain, but there are many permanent pools along its bed.

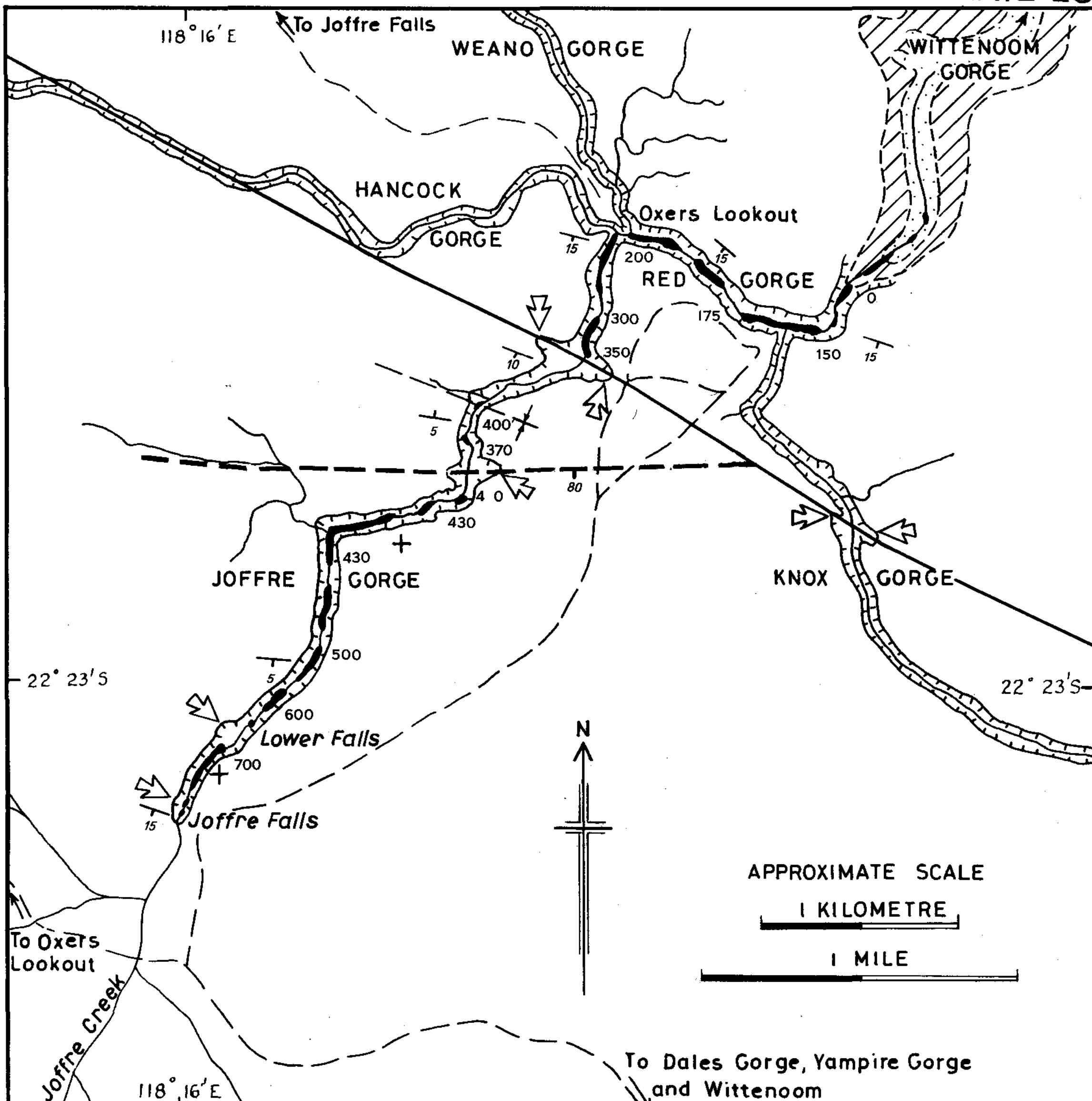
A rough drillers' track, closed to public access, continues southward for a further 3 miles up Wittenoom Gorge past the old Wittenoom mine, during which the cliffs of the Dales Gorge Member on either side become steeper and closer together. The track terminates just below a long pool which marks the southernmost outcrop of the Dales Gorge Member in the gorge (Plate 25). Farther upstream the first cliffs of the Joffre Member present an even more formidable obstacle than those of the Dales Gorge Member; half a mile south of the end of the track (at the figure '150' on Plate 25) Joffre Creek makes an abrupt right-angled bend, above which it flows east-southeast (Plate 27, A and B) for about ¾-mile; this section of the gorge of Joffre Creek is known as Red Gorge. At the upper (western) end of Red Gorge there is another right-angled bend, above which the creek flows in a general northeasterly direction for about 2¼ miles below Joffre Falls; this section is here called Joffre Gorge (Plate 25). Weano Gorge, Hancock Gorge and Knox Gorge are tributary gorges of the main Joffre Gorge—Red Gorge—Wittenoom Gorge drainage line of Joffre Creek.

There is steep but easy access between top and floor of both sides of Wittenoom Gorge where the Whaleback Shale Member crosses it. The right-angled bend half a mile farther south, where Wittenoom Gorge meets Red Gorge, marks the farthest point of dry access along the gorge floor, since the effectively vertical cliffs rise directly from the edges of the pool in Red Gorge (Plate 27, A and B). Upstream from this point, access to the main gorge from above is possible without mountaineering equipment at only six points: on both sides of the gully formed by the dolerite dyke, on the east side of the fault crossing, on the west cliffs at the Lower Falls, down a gully just below Joffre Falls (Plate 28D) and at Joffre Falls. No part of the gorge is recommended for recreational climbing, since the iron formation is well jointed, and liable to piecemeal collapse without warning. All of these access points except Joffre Falls, are marked by arrows on Plate 25. Access to Knox Gorge is possible at the dolerite dyke, but it is not known whether this gorge can be followed down to Red Gorge. Access to Red Gorge is reported to be possible down Hancock Gorge, but it joins the main gorge at a pool. A vertical cliff at the mouth of Weano Gorge denies access to Red Gorge by this route.

All parts of the gorges shown on Plate 25 except the outlet into Wittenoom Gorge, are best approached by the track shown entering from the south. This is reached from a southward turning off the main Wittenoom—Roy Hill road 15 miles east of Wittenoom; thereafter it is signposted to Joffre Falls. The road climbs up on to the gently undulating Hamersley plateau, into which the gorges are incised, by way of Yampire Gorge. The tracks shown extending northeastwards from Joffre Falls are only roughly graded, and their positions may change from year to year. The track which continues outside the eastern and northern edges of Plate 25 to connect Joffre Falls and Oxers Lookout is a very rough private road which is open to visitors as a courtesy. Oxers Lookout is a spectacular observation post overlooking the confluence of Joffre, Hancock, Weano and Red Gorges. A direct road linking Wittenoom Gorge and Oxers Lookout is strictly private, and normally closed by locked gates; any attempt to use it if the gates are open would be not only an offence, but also extremely dangerous.

The initial descent of Joffre Creek from its open valley on the Hamersley plateau into Joffre Gorge takes place abruptly over 120 feet of the stepped, amphitheatre-like Joffre Falls. The top-most edge-to-edge width of the gorge there averages about 150 feet (Plate 28D). The gorge widens above the Lower Falls (Plate 25), which drop more gradually another 100 feet to increase the height of the gorge walls to about 220 feet, with little increase in width. Within the next half mile downstream the gorge floor slopes down quite steeply in steps made up of huge boulder piles, and the wall height increases to about 300 feet with a topmost width of about 150 feet and a floor width of about 20 feet (Plate 28B). This height, locally increasing or decreasing slightly, is maintained throughout the remainder of the courses of Joffre and Red Gorges; in Red Gorge the top width increases to about 350 to 400 feet, and the floor, or

PLATE 25



LEGEND TO GEOLOGICAL AND TOPOGRAPHIC SYMBOLS

- Geological boundary
- Fault plane with dip (80)
- Axial plane trace of syncline
- Strike and dip of bedding (5)
- Bedding close to horizontal
- Dolerite dyke
- 450 — Stratigraphic level of adjacent gorge floor in feet above base of Joffre Member
- Steep sides of gorge
- Descent possible
- Stream with permanent pools
- Tracks

STRATIGRAPHY

(Surficial deposits omitted)

- Joffre Member
- Whaleback Shale Member
- Dales Gorge Member

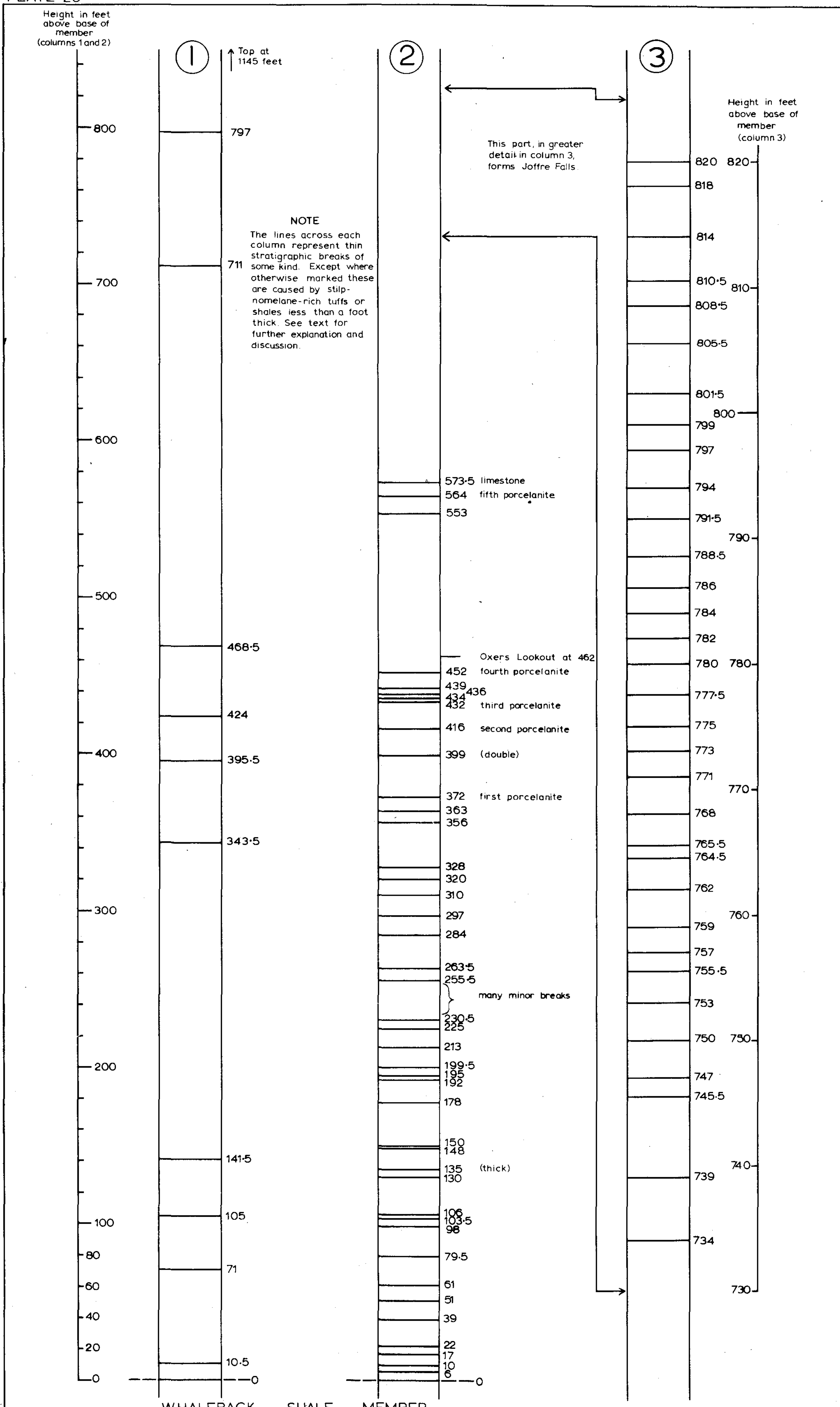
Note: These are the lower three of the four members of the BROCKMAN IRON FORMATION of the Hamersley Group.

SKETCH MAP SHOWING

THE STRUCTURE AND STRATIGRAPHY OF THE JOFFRE MEMBER

IN THE GORGES SOUTH OF WITTENOOM

10557



MEASURED STRATIGRAPHIC SECTIONS OF PART OF THE JOFFRE MEMBER OF THE BROCKMAN IRON FORMATION, AT THE TYPE SECTION (COLUMN 1) AND IN THE GORGES SOUTH OF WITTENOOM (COLUMNS 2 AND 3).

pool, width to about 30 to 50 feet (Plate 27, A and B). Here, buttresses topped by grass slopes locally relieve the wall-like sides, but these are never sufficiently extensive to provide practicable access.

METHODS OF WORK

To measure a continuous section of the Joffre Member between the uppermost part of Wittenoom Gorge and Joffre Falls, a light portable raft was constructed using a camp bed and three inflated inner tubes; it can be seen floating on Plate 28B. This provided ample buoyancy for one person and all necessary equipment and rock samples; it was light enough to be easily carried between pools, stable enough to be boarded in awkward positions among slippery boulders, and could be paddled easily. More sophisticated craft would probably have few advantages for the purpose.

A 6-foot wooden pole marked in feet was used for measurement. It proved more practical than a tape for working along smooth cliffs rising directly from the water. Marks were made on the gorge walls at 10-foot intervals using white aerosol paint. The interval was increased in the later part of measurement to conserve paint. The measurement occupied two full days, using the access point at the dolerite dyke for the division into two sections.*

STRUCTURE

The Joffre Member in the area of the gorges forms part of the south-southwesterly dipping north limb of a broad open synclinorium (the Hamersley Range synclinorium) whose axial plane trace runs west-northwest to east-southeast not far south of Joffre Falls. The comparatively mild folding displayed on Plate 25 consists of small departures from this regional dip of about 5°. It will be appreciated from Plates 27 and 28 that folding is not intense, and that the rocks, for their age, have been subject to exceptionally slight deformation.

The single dolerite dyke of Plate 25 has a probable thickness of about 20 feet where it crosses Joffre Gorge, and dips at 80° southwestward. There is an upward displacement of 40 feet on this side, so that the plane of the dyke is a reverse fault. The fault which crosses the gorge farther south dips at 80° to the south and has a normal displacement of 30 feet. It is possible that the gentle syncline, whose axial plane trace bisects the angle between the dyke and the fault, is related to the same stress system which caused them, but this is uncertain, since it is not known whether the fault or the dyke has a lateral component of movement. Also, the fault is terminated at the dyke on Plate 25 by air photo interpretation; its extrapolated transection of Knox Gorge was not examined on the ground. Just north of the fault in Joffre Gorge a reverse (thrust) fault with a southerly dip of about 30° and a throw of only a few feet passes downwards into a small fold and finally dies away in undisturbed iron formation.

It is a structural characteristic of iron formations in the Hamersley Range area that while folds may be mapped and described on any chosen scale, they normally lie within structural components of larger folds and contain within themselves smaller folds on all scales down to very small puckers (Trendall and Blockley, in press). The strike variations along the line of Red Gorge (Plate 25) are probably related to open folds with southwesterly trending axes (compare Dales Gorge; Trendall 1966), but more work is needed, particularly on the tributary gorges, before the status of these can be known.

Many of the short, straight sections of the gorges are evidently controlled by principal joint directions, as at Dales Gorge (Trendall, 1966), but no measurements were carried out. The exact mechanism of joint control versus control by a former open valley of Joffre Creek is a difficult problem involving the regional geomorphological history, and is not discussed here.

* In August, 1966, the writer, together with J. G. Blockley and P. C. Muhling, swam and walked from the mouth of Red Gorge to the top of the Lower Falls, in one day. This appears to be the first recorded traverse of the gorges, and cannot be recommended as a geological excursion, since the water in all the pools is always very cold.

STRATIGRAPHY

The main type of lithological discontinuity within the predominant and rather uniform iron formation of the Joffre Member is stilpnomelane-rich shale in bands between about an inch and about a foot thick. After identification of the base of the member (see under next heading) the heights of the mid-points of the thicker of these bands above the base were measured, and appear on Plate 26, columns 2 and 3. All measurements were recorded to the nearest 0.5 feet. The judgment as to whether a shale was thick enough to record was made subjectively, and may have varied through the section; any break large enough to have some potential use for field correlation was recorded. Note that the thicknesses of these shales were not recorded, and that they therefore appear with equal status on Plate 26. The shale at 135 feet is the thickest, at about a foot. That at 399 feet consists of two shales, each about 6 inches thick, separated by between one and two feet of iron formations. Wherever two shales, such as these, are separated by only a foot or two of iron formation, they tend to undulate antipathetically in open folds with a wavelength of about two or three feet, similar to those illustrated above the third porcelanite in Plate 28C.

Trendall and Blockley (in press) applied the name black porcelanite to tough flinty material in the Joffre Member consisting largely of potassic feldspar; they thought it was probably a tuff. Five bands of porcelanite were found, and also appear on Plate 26. Of these, the third is thickest (Plate 28C) and the best stratigraphic marker (Plate 27, A and B). The first porcelanite is about a foot thick, the fourth and fifth (Plate 28B) about 6 inches, and the second only about 3 inches. The lower four porcelanites all lie within 80 feet (Plate 28A). A band of yellow-weathering limestone about a foot thick occurs at 573.5 feet (Plate 28B). It has a coarse calcite mosaic, with siderite and stilpnomelane.

In spite of the subjectivity in measuring shales the following valid generalizations about gross lithological variation within the member may be made from Plate 26:

1. There is little variation between the base and the first porcelanite at 372 feet (Plate 27, A and B).

2. The lower four porcelanites form a potentially useful assemblage for identification (Plate 28A).

3. Between the fourth porcelanite at 452 feet, and 734 feet, the iron formation is uniform and similar to that below the lower four porcelanites; the fifth porcelanite is inconspicuous (Plate 28B), and the limestone of doubtful significance (see under following heading).

4. Between 734 and 820 feet, at least, frequent thin shales are regularly arranged with an average (32 intervals) separation of 2.7 feet, to give a distinctively flaggy appearance (compare Plate 28, B and D).

At Joffre Falls exposures continue to a maximum height of about 900 feet above the base of the member, but the quality of exposure deteriorates above 830 feet. The full thickness of the Joffre Member in this area is not known.

LATERAL CORRELATION WITHIN THE MEMBER

The discontinuities recorded by Trendall and Blockley (in press) in the lower part of the less cleanly exposed type section of the Joffre Member at Yandicoogina Creek appear in column 1 of Plate 26. It is clear that no confident correlation between the two sections can be made without further work.

The limestone of the Joffre Member closely resembles those locally present in some S macrobands of the Dales Gorge Member (Trendall and Blockley, in press). These are products of diagenetic modification of shale, and their lateral discontinuity is demonstrable. Use of the Joffre Member limestone for attempted regional correlation should therefore be made with care.

Of the core of Hole 47A used for the type section of the Dales Gorge Member (Trendall and Blockley, 1968) a further 358.1 feet are stored in the collection of the Geological Survey of Western Australia. This length includes a complete section of the Whaleback Shale Member, 215.2 feet thick, and 142.9 feet of continuous core upwards from the base of the Joffre Member, to the drilling depth of about 500 feet where core recovery began. It is easy in this core to select a natural lithological junction between the Whaleback Shale Member and the Joffre Member, and this was identified confidently and marked in the gorge (Plate 27C), at a point just over 3 miles from the site of the drillhole. From the broad similarity between the Dales Gorge Member and the Joffre Member in small-scale stratification (Trendall and Blockley, in press) the achievement of this correlation is not surprising. It is to be expected, but it is not yet demonstrated, that small-scale correlation within the Joffre Member is equally possible on a basin-wide scale, and the establishment of the stratigraphic section reported here should serve as the basis for future investigation of this.

IDENTIFICATION OF PUBLISHED DATA

The identity of a part of the Joffre Member illustrated by MacLeod (1966, Figure 13) is given in the caption of Plate 28D.

Of the illustrations of parts of the Joffre Member used by Trendall and Blockley (in press) their Figure 19B is just over 345 feet above the base, the boys in Figure 19C are standing on the 784-foot discontinuity (Plate 26, column 3), the surface illustrated in Trendall and Blockley's Figure 39A appears in the right hand corner of Plate 28D and is at about 720 feet, and the cross-podded structure in Figure 39D comes from about 725 feet. Of the chemical analyses reported by Trendall and Blockley (in press) analysis 4 of their Table 16 is of stilpnomelane-rich shale at 734 feet, while analysis 5, of black porcelanite, is from the first porcelanite, at 372 feet.

FIELD GUIDE

For dryshod examination of the Joffre Member the best places, in order of ease of physical accessibility, are:

(1) Joffre Falls, where the section between 715 and about 850 feet is well exposed.

(2) At the dolerite dyke, and thence along the gorge floor for about half a mile upstream, the section between about 340 and 450 feet, with the lower porcelanite is cleanly exposed, and increasingly weathered parts are accessible for about 150 feet higher.

(3) At and below the Lower Falls the section below the Joffre Falls exposures, down to about 540 feet, is very well exposed. Descend into the gorge, and down the falls, with care!

(4) The base of the member, and higher levels to about 200 feet, are best reached up Wittenoom Gorge.

Good exposures of the section between 200 and 340 feet are only available in Red Gorge, and these are not accessible dryshod; it is possible that Knox Gorge may provide better exposures here. Oxers Lookout (Plate 28A), and the south cliffs of Red Gorge (Plate 27, A and B) provide excellent views of the stratigraphy, which interested visitors will not wish to miss, but fresh rock is nowhere available along the edges of the gorges.

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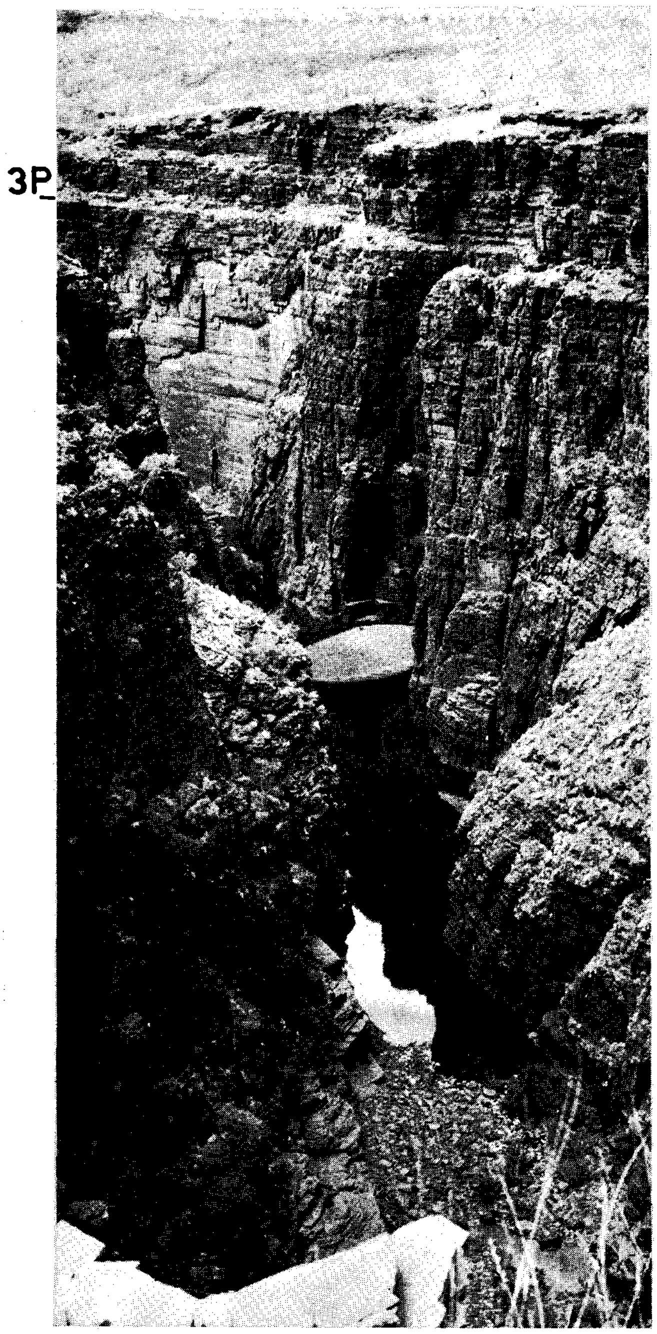
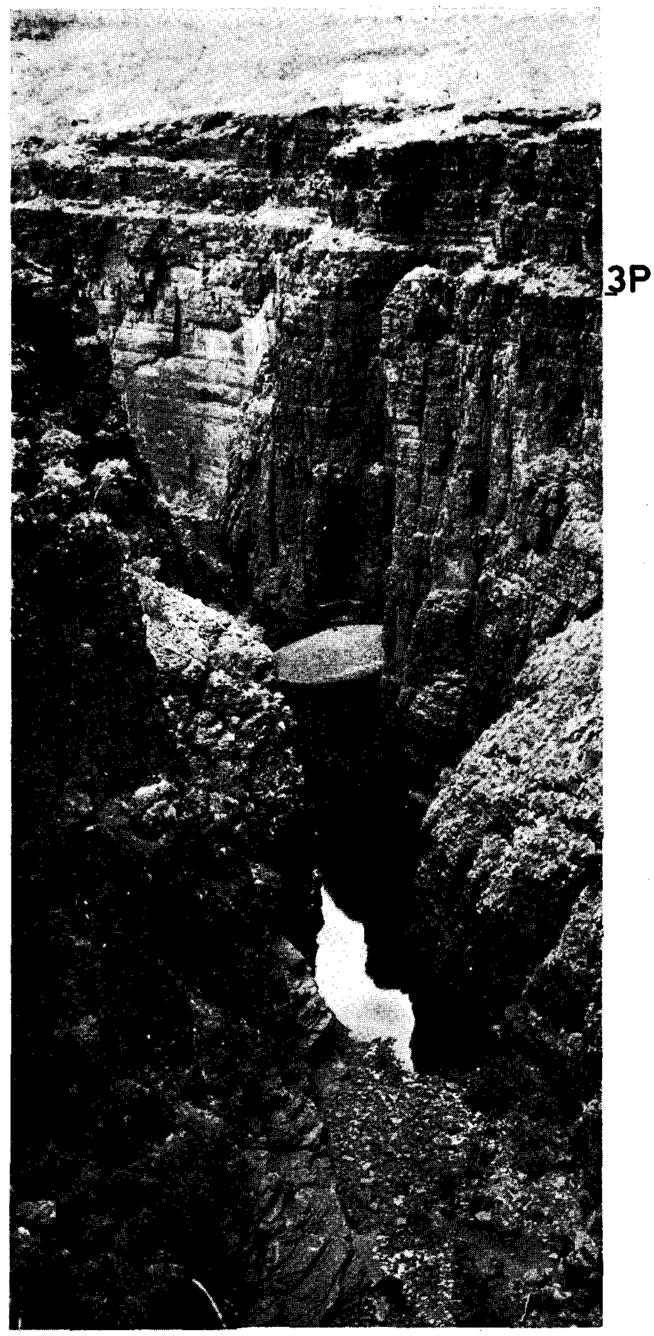
PLATE 27 (opposite)

A and B. Stereoscopic pair of photographs looking east-southeastwards down the lower part of Red Gorge from the edge of the cliffs on the south side at a point just above the figure 5 in the number 175 on Plate 25. Note the smooth flat Hamersley plateau surface in the background continuing evenly to the sharp crest of the cliffs, which reach a maximum height of about 330 feet with much of their slope close to vertical. The farthest visible end of the pool is at the right-angled bend at the mouth of Red Gorge, and is the highest point accessible on foot up Wittenoom Gorge. The coarse gravel bank in the centre of the photograph, which appears to (but does not) divide the pool into two parts, is washed out at the mouth of Knox Gorge. The third porcelanite (Plate 28C) is marked 3P, and forms the most conspicuous stratigraphic marker. The second break about 40 feet above it, best seen in the farthest cliffs, is caused by a group of strongly podded cherts (see Plate 28A) which is not shown on Plate 26, column 2. The vertical cliffs immediately behind the gravel bank demonstrate the relative homogeneity of this lower part of the Joffre Member (compare Plate 28D); between water level at 160 feet and the third porcelanite at 432 feet the intervening shales can be picked out using Plate 26. The first and second porcelanites and the shales at 399 and 320 feet are the most conspicuous; other measured shales have no greater status than some unrecorded ones, which illustrates the subjectivity of measurement referred to in the text.

C. Photograph looking west-northwestward across the downstream end of the pool in the uppermost part of Wittenoom Gorge which is crossed by the base of the Joffre Member (Plate 25). The base of the member, and thin stilpnomelane shales at 6, 10, 17, 22 and 39 feet are marked at the right hand side. A paint mark showing the base of the member can be seen about 4 feet above water level just above a small twin tree at the lower margin of the photograph about one-third of the width in from the right hand margin. The positions of other paint marks at 50 and 60 feet are marked by white pointers. Other marks showing stratigraphic position were painted just outside the right hand edge of the photograph in 1968, and should remain visible for some years.



A



B

C

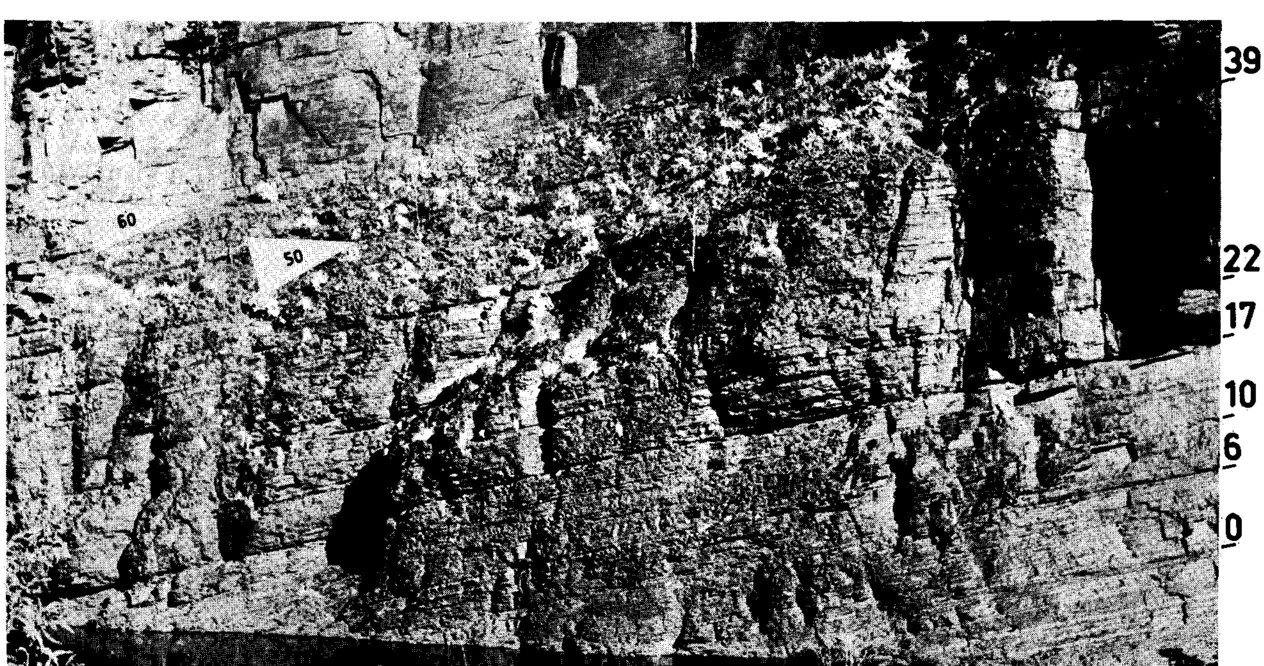
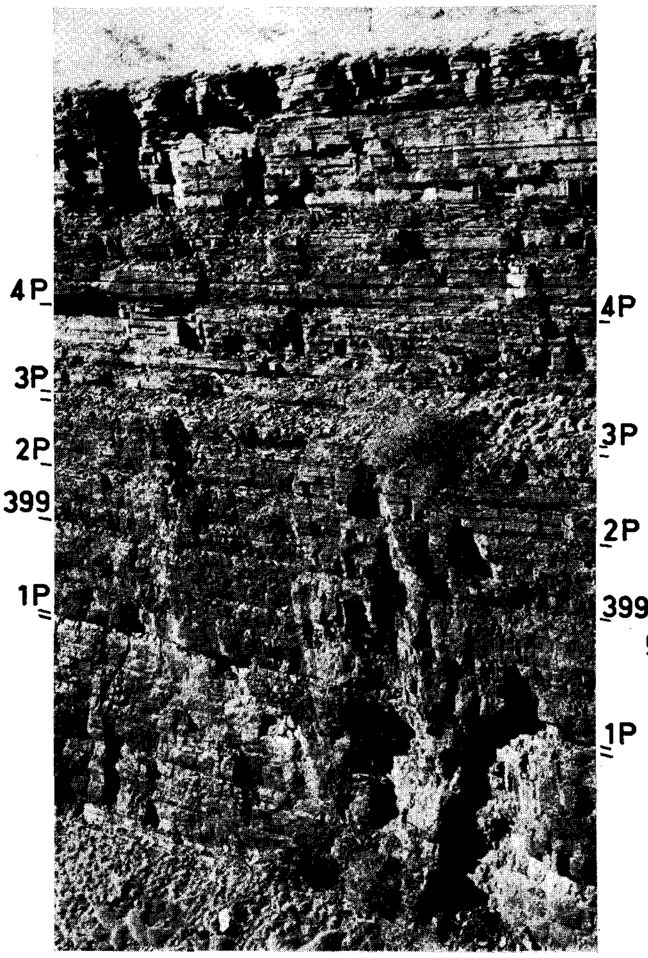
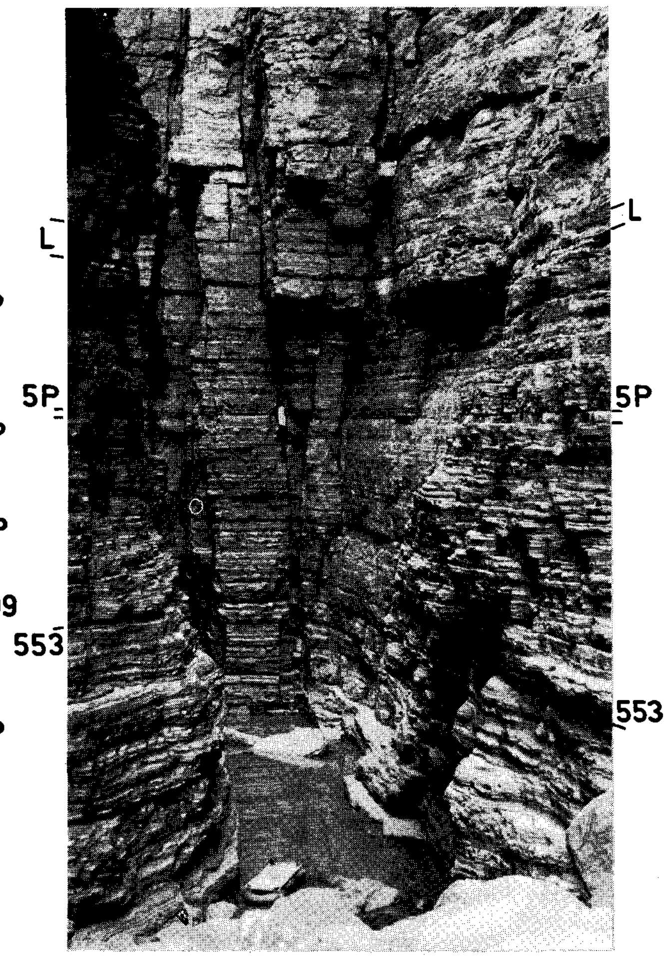


PLATE 28



A



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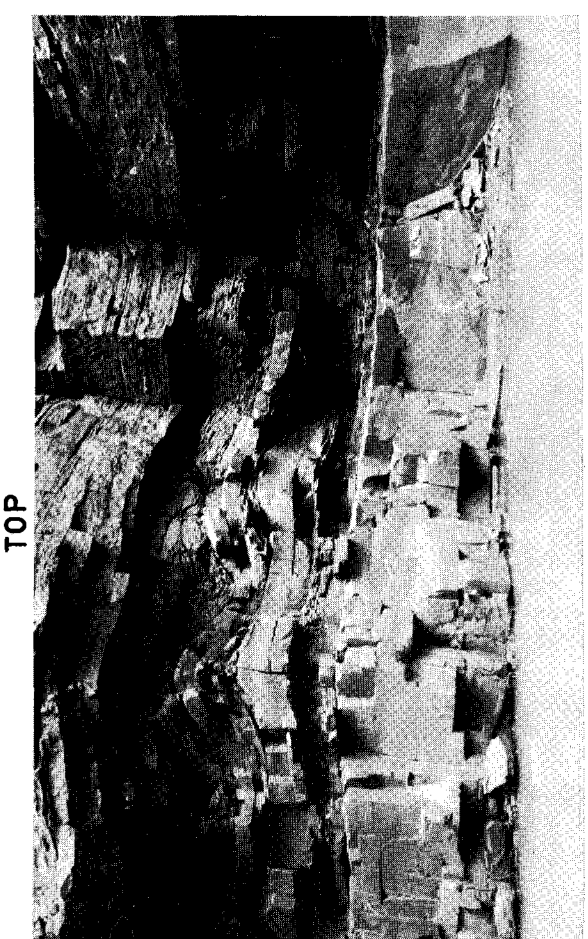

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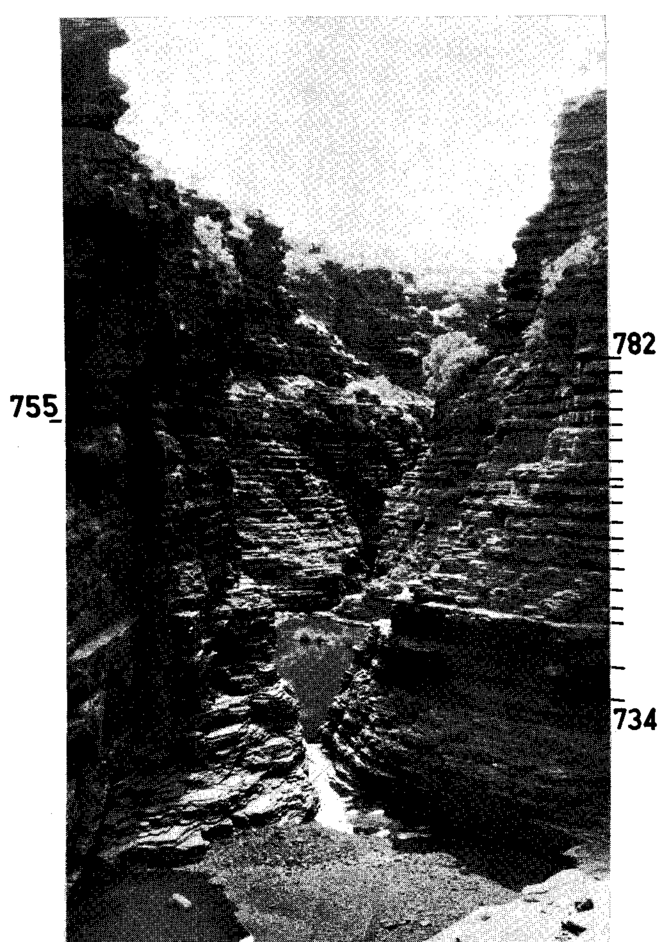


D

PLATE 28 (opposite)

A. Photograph of the topmost cliffs of the south side of Red Gorge, looking south-southeastward from Oxer's Lookout (Plate 25). The lower four porcelanites are marked 1P to 4P, and the double shale at 399 feet is also indicated. The band with strongly podded cherts about 40 feet above the third porcelanite (the fourth porcelanite is 20 feet above the third porcelanite), which forms a break in the cliffs farther eastwards down the gorge (Plate 25, A and B), can be clearly seen.

B. Photograph looking northeast down Joffre Gorge about half a mile downstream from Joffre Falls; the pool is that just above the figure 600 on Plate 25. The camera was held exactly in the plane of the fifth porcelanite, which is marked 5P. The limestone 9.5 feet above and the thin shale 11 feet below are also marked. The limestone, as in the cliffs above the central point of the photograph, often runs immediately below overhanging ledges. The raft used during measurement floats in the pool. The smaller width of this upper part of the gorge contrasts with Plate 27A and B. Note the size of the boulders in the foreground and in the pool; they commonly weigh up to 10 tons.

C. Photograph looking north at the third porcelanite at the foot of the cliffs of Joffre Gorge about 1¼ miles downstream from Joffre Falls, just under the 'r' of the word 'Gorge' on Plate 25. The base of the porcelanite, which is about two feet thick, is exactly at water level. Immediately above it the interbedded shale and iron formation are characteristically thrown into irregular 'rolls' with an amplitude of about a foot; these structures have no consistent axial direction. The composition of the porcelanite (largely potassic feldspar) accounts for the contrast between its tough blocky appearance here, where it is fresh, and its obviously greater susceptibility to weathering than the iron formation in A and Plate 27, A and B.

D. Photograph looking north-northeastwards down Joffre Gorge from a point halfway up Joffre Falls. The thin stilpnomelane shales between 734 and 782 feet, shown in column 3 of Plate 26, are marked on the right hand (east) side. The 775-foot discontinuity only is marked on the left hand side, from which the remainder may be counted up or down and compared with those across the gorge. Note that on the right, the twin shales at 764.5 and 765.5 appear as one discontinuity. Figure 13 of MacLeod (1966) was taken from near the base of the west cliffs close to the head of the long pool above the Lower Falls (Plate 25); the head of the pool is just visible in the central part of this photograph. MacLeod's Figure may be related to the stratigraphic scale given here for the Joffre Member by marking '730' on its right hand margin 2.3 cm up from the lower edge, by marking '739' similarly 3.9 cm up, and by equally subdividing 9 feet between the marks. The stratification here at a mean interval of 2.7 feet contrasts with the typically massive appearance at lower levels (B of this Plate, and Plate 27, A and B). Access may be gained to the gorge here by the steep gully which runs down to the central pool (with grass clumps) behind the buttress in the left foreground.

A COMPARISON OF SOME VOLCANIC ROCKS OF UNCERTAIN AGE IN THE WARBURTON RANGE AREA

by R. Peers

ABSTRACT

Four occurrences of basaltic rocks are known from the Officer Basin of Western and South Australia: the Officer Volcanics, intersected between 2,405 and 2,764 feet in the oil test well Yowalga No. 2, the Table Hill Volcanics on the Talbot 1:250,000 Sheet area, some un-named volcanics on the Cooper 1:250,000 Sheet area, and the Kulyong Volcanics on the Birksgate 1:250,000 Sheet area. The Officer, Table Hill, and Kulyong Volcanics are all vesicular and massive tholeiitic basaltic rocks.

Examination of specimens from each of these sequences of volcanic rocks demonstrates the petrographic similarity of these basalts and suggests that they may in fact be contemporaneous and co-magmatic. The un-named basalts on the Cooper 1:250,000 Sheet area are deeply weathered and were not examined at all. Results of Rb/Sr and K/Ar isotopic age-dating on the Officer Volcanics have been interpreted as indicating an age of about 1,000 m.y. (Proterozoic). K/Ar isotopic age-dating on the Kulyong Volcanics gave an age of 475 ± 20, 485 ± 20 m.y. (Ordovician). The Table Hill Volcanics have not been dated. It is suggested that further isotopic age-dating will prove that these basalts are co-magmatic and of the same age (probably Ordovician).

INTRODUCTION

Four occurrences of basaltic volcanic rocks are known in the Officer Basin of Western and South Australia, the Officer Volcanics intersected in Yowalga No. 2, the Table Hill Volcanics, the un-named volcanics on the Cooper 1:250,000 Sheet area, and the Kulyong Volcanics (see Figure 12).

Yowalga No. 2 oil test well on the northeastern corner of the Breaden 1:250,000 Sheet area was drilled for the Hunt Oil Co.—Placid Oil Co. in 1966. It passed through a formation consisting of vesicular and massive basalts, and named the Officer Volcanics, between 2,390 feet and 2,775 feet. The Officer Volcanics unconformably overlie the Babbagoola Formation and are in turn overlain by the Lennis Sandstone.

Three samples of Yowalga No. 2 basalt were submitted to three independent contractors for isotopic age determinations. Both the potassium/argon and rubidium/strontium methods were applied, and the following results obtained.

Depth	Method used	Isotopic Age (in millions of years)	Contractor
2417'–19' (Core 3)	Rb/Sr	1,000	A.N.U.
2417'–19' (Core 3)	Rb/Sr	446	A.N.U.
2422' (Core 3)	K/Ar	357	Geochron
2422' (Core 3)	K/Ar	331	Isotopes, Inc.
2760' (Core 4)	Rb/Sr	1,143	A.N.U.
2760' (Core4)	K/Ar	447	Geochron
2760' (Core 4)	K/Ar	445	Isotopes, Inc.

Jackson (1966) discussed and interpreted these results and came to the following conclusions. The ages of 331-357 million years and 445-447 million years (Devonian or Ordovician) are interpreted as being the age of metamorphism in the basalts of Yowalga No. 2. It should be noted that the degree of 'metamorphism' is very mild and may be interpreted as deuteric alteration, weathering, or a combination of both. The crystallization age of the basalt is taken by Jackson as Upper Proterozoic, or at a minimum of 1,000 million years.

Birksgate No. 1 stratigraphic well, 35 miles southeast of the Kulyong Volcanics, was drilled to 6,160 feet and bottomed in an arkose which is tentatively correlated by geologists of the South Australian Geological Survey with the Lennis Sandstone in Yowalga No. 2 well (written communication). Rb/Sr isotopic ages of 845 ± 250 million years were obtained from shales in Birksgate No. 1 between 3,170 and 3,180 feet depth.

The Table Hill Volcanics crop out over an area of about 16 square miles on the Talbot 1:250,000 Sheet area, and are composed of fine-grained massive, and vesicular basaltic rocks. They are unconformably overlain by glacial sediments of probable Permian age, and in turn overlie glacial deposits of Upper Proterozoic age from which they are probably separated by an unconformity (J. L. Daniels, personal communication). Unfortunately no age-dating has been carried out on any of the samples from the Table Hill Volcanics.

The un-named volcanics on the Cooper 1:250,000 Sheet area were visited by members of a mapping party of the Geological Survey of Western Australia during the field season of 1967. They are deeply weathered, fine-grained basic volcanic rocks

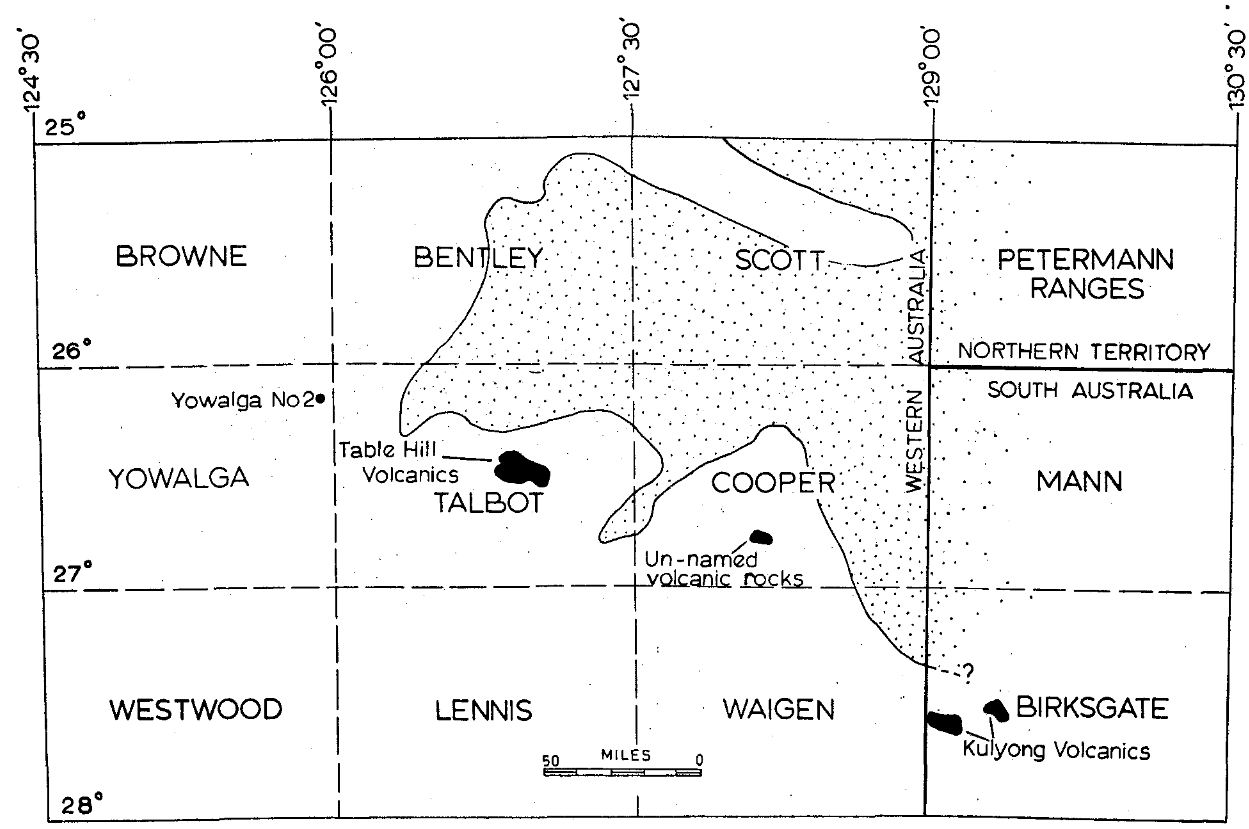


Figure 12. Distribution of volcanic rocks and Precambrian rocks in the Officer Basin.

(J. L. Daniels personal communication), and will not be discussed further in this report.

The Kulyong Volcanics are located on the Kulyong 1:63,360 Sheet area of the Birksgate 1:250,000 Sheet area. The volcanics at the type section (lat. 27° 36′ 20″S, long. 129° 26′ 00″E) are 10 feet thick and composed of both massive and vesicular basaltic rock (Major and Teluk, 1967). The Kulyong Volcanics overlie a red-brown sandstone. No rocks have been seen overlying and in contact with the volcanics, and there is no evidence such as chilled margins, disturbance, or erosion of a former upper contact. Major and Teluk (1967) refer to the occurrence as "a flow or intrusion", so it would appear that there is no field evidence as to the form of these volcanics, and whether they are in fact extrusive or intrusive.

The Kulyong Volcanics were dated by Isotopes, Inc. using the K/Ar method, and the following results obtained.

Sample number	S.A. Mines Dept petrological no.	Isotopic age (in millions of years)
18013	P671/66	485 ± 20
18014	P672/66	475 ± 20

The Ordovician age is supported by regional mapping in South Australia (written communication from South Australia Department of Mines).

The purpose of this report is to compare the petrography of the basalts from Yowalga No. 2, the Kulyong Volcanics, and the Table Hill Volcanics.

ACKNOWLEDGEMENTS

I wish to thank the Director of the South Australia Department of Mines for the loan of thin-sections of specimens from the Kulyong Volcanics, and for access to the two reports on these volcanic rocks by A. B. Simpson of the Australian Mineral Development Laboratories, Adelaide (1966a, 1966b).

PETROGRAPHY OF THE OFFICER VOLCANICS

Three cores were taken from the Officer Volcanics Formation.

Split halves of each core are stored at the core library of the Geological Survey. The following samples were selected for thin-sectioning and examination.

Core number	Depth From	Depth To	Amount recovered
2	2,405′	2,413′	1′6″
3	2,413′	2,423′	9′6″
4	2,754′	2,764′	10′0″

Core 2—between 2,404′ and 2,413′
Core 3—2,419′ (approx)
Core 3—2,421′ „
Core 3—2,323′ „
Core 4—2,756′ „
Core 4—2,759′ „
Core 4—2,764′ „

These samples conveniently fall into two groups, (a) altered amygdaloidal basalt at depths of between 2,404 and 2,413; 2,419, 2,421 and 2,423 feet, and (b) unaltered basalt at depths of 2,756, 2,759, and 2,764 feet.

The following descriptions are based primarily on the report of the consultant petrologist (J. E. Glover) from the completion report for Yowalga No. 2 (Jackson, 1966).

ALTERED AMYGDALOIDAL BASALTS

Hand specimen. The altered amygdaloidal basalts are both amygdaloidal and slightly porphyritic. They are composed of rare phenocrysts of pink feldspar set in a fine-grained, dark pinkish-brown groundmass. Their most striking feature however is the presence of numerous, more or less round, bright green amygdales, with maximum diameters of 5 mm.

Thin-section. The phenocrysts are subhedral and range up to 1.5 mm in length. They are composed of plagioclase which is so altered to a mixture of clay, hematite, and minor epidote as to preclude a more specific identification. However, refractive index determinations by Glover (1966), indicate the present composition to be albite. Multiple twinning can still be distinguished. In the sample taken from between 2,404′ and 2,413′, the plagioclase phenocrysts are evenly and normally zoned from labradorite to andesine, and only slightly altered to albite, sericite, and chlorite.

The groundmass is composed of a meshwork of plagioclase laths up to 0.5 mm long, with interstitial pale green chlorite and a turbid brown material which may be devitrified glass now represented by hematite-impregnated K-feldspar. Some of the cloudy patches may represent altered pyroxene, but none of the original mineral remains. Skeletal frameworks of magnetite commonly enclose patches of antigorite. The shape of many of these grains is strongly reminiscent of olivine, but none of the original mineral remains to support this conjecture, and they could equally well be pyroxene pseudomorphs (see Plate 29F).

The amygdales vary considerably in size, and their contents have been identified by the Government Chemical Laboratories as mainly chlorite with smaller amounts of hematite, muscovite, and calcite (see Plate 30A, B, and C). In well-developed amygdales the sequence from margins to centre is: chlorite, a mixture of chlorite and muscovite, and muscovite (see Plate 30B). In most amygdales however, chlorite is the predominant mineral developed. The specimen from between 2,404′ and 2,413′ has no vesicles *sensu stricto*, but has developed irregular patches infilled with chalcedony and commonly rimmed by hematite. It is grouped with the amygdaloidal basalts because it seems to have stronger affinities here than with the massive basalts.

Opaque minerals include anhedral grains of magnetite and hematite. Texturally these rocks may be described as intersertal and amygdaloidal (see Plate 29B).

UNALTERED BASALTS

Hand specimen. The unaltered basalts are very basalts are brownish-green, reddish-brown, or dark grey. They have no amygdales, lack any obvious fabric and are composed of an interlocking meshwork of plagioclase and pyroxene crystals.

Thin-section. The predominant minerals are plagioclase and clinopyroxene. Plagioclase forms altered laths up to 1.5 mm long which are normally zoned from bytownite to labradorite. Two clinopyroxenes are present. The coarser-grained, relatively unaltered pyroxene with the moderate 2V is augite. The calcium-poor equivalent, pigeonite, forms smaller anhedral grains which are extensively altered to uralite, and stained by hematite. Pigeonite is more abundant than augite.

Other minerals include anhedral magnetite and hematite grains. The interstitial material is a brown, poorly crystallized mineral of low relief which may be K-feldspar, and probably represents devitrified glass, with minor chlorite. These areas include numerous minute grains of hematite and acicular crystals of apatite. The texture of these rocks varies from subophitic to intergranular (see Plate 29A).

PETROGRAPHY OF THE KULYONG VOLCANICS

The following descriptions are based on the two petrological reports made by A. E. Simpson of the Australian Mineral Development Laboratories, Adelaide, with some modification suggested by my own examination of thin-sections of samples from the Kulyong Volcanics kindly made available by the South Australian Department of Mines.

Four samples are considered, P671/66 (T.S.18013), P672/66 (T.S.18014), P1042/66 (T.S.18288), and P1043/66 (T.S.18289).

N.B. The numbers are those of the South Australian Department of Mines collection.

FINE TO MEDIUM-GRAINED BASALT

Hand specimens. The fine to medium-grained basalts are brownish-green, reddish-brown or dark grey. They have no amygdales, lack any obvious fabric and are composed of an interlocking meshwork of plagioclase and pyroxene crystals.

Thin-section. The textures developed in these holocrystalline basalts vary between subophitic and intersertal, and all except specimen 18014 are sparsely porphyritic with scattered plagioclase phenocrysts up to 0.8 mm long (see Plate 29C). The predominant minerals are plagioclase and pyroxene. The plagioclase is polysynthetically twinned and normally zoned from labradorite to andesine in all except specimen 18289 where it is zoned from labradorite to a more sodic labradorite. The lath-shaped plagioclase crystals range between 0.1 mm and 0.5 mm in length and are sometimes extensively sericitized.

Three pyroxenes occur in this group of rocks, a calcic clinopyroxene, its calcium-poor equivalent, pigeonite, and an orthopyroxene. The calcic clinopyroxene (augite) occurs in each thin-section, and has a $2V\gamma$ of 40° or more. It is colourless to pale brown and partly altered to bastite and uralite(?). Simpson (1966) reports very fine exsolution lamellae of pigeonite(?) developed parallel to the (001) plane of the augite in specimen 18288. This may in fact be a preferential development of alteration products along the (001) cleavage. Hematite is commonly concentrated along cleavage and fracture planes of the augite. Orthopyroxene occurs only in specimen 18288, and is subordinate to the augite which commonly mantles it. In specimen 18289 the predominant pyroxene is pigeonite with the co-existing augite forming larger crystals by comparison.

Scattered grains of an opaque mineral (magnetite or titanomagnetite) altering to limonite and hematite occur throughout these rocks, and general hematite staining is widespread.

The interstitial areas of these rocks are variously composed of a devitrified glassy mesostasis (alkali feldspar?) and chlorophaeite. A poorly crystallized brownish material of low relief occurs in all except specimen 18014. Simpson (1966) regards this material as a devitrified glassy mesostasis which includes minute grains of hematite and acicular apatite crystals. For specimen 18288 Simpson (1966) suggests that this material is actually an alkali feldspar. It seems likely that all of the brownish interstitial material in these rocks is an alkali feldspar heavily charged with hematite and other products of incipient crystallization as the result of devitrification of an acid glass. Specimen 18014 has in addition a patchy development of an olive green material which Simpson (1966) identified as chlorophaeite (see Plate 30E). Sarbadhikari and Bhattacherjee (1966) suggest that chlorophaeite is a mixture of clay minerals (montmorillonoids, vermiculite and kaolinite) chiefly derived by the alteration of pyroxenes, iron ores, and primary glass. The specific mineralogical composition of this chlorophaeite is unknown, as it its genesis. In specimen 18289 Simpson (1966) notes that "certain other cavities in the rock are filled with a colloform deposit of a brownish fibrous silica mineral with low birefringence which is probably ?lussatite". Lussatite is defined by Frondel (1962) as a fibrous cristobalite. The colloform mineral in question is certainly a fibrous form of silica, but it may be either lussatite or chalcedony (see Plate 30D).

Major and Teluk (1966) report that the lower seven feet of the Kulyong Volcanics are vesicular, but none of this vesicular basalt was available for examination.

PETROGRAPHY OF THE TABLE HILL VOLCANICS

Seven specimens from this formation were selected, thin-sectioned and described. Six (specimens 18206, 18210, 18212, 18214 and 18216) are fine-grained massive basalts, and specimen 18209A is an amygdaloidal basalt. A description of the altered amygdaloidal basalt, and a composite description of the six massive basalts follow.

ALTERED AMYGDALOIDAL BASALT

Hand specimen. The altered amygdaloidal basalt is a very fine-grained pinkish brown rock. The amygdales comprise some 50 per cent of the rock and are infilled with a yellow-green material which has been leached from the weathered surfaces leaving a scoriaceous framework.

Thin-section. Examination reveals that the specimen is highly altered. Euhedral and subhedral plagioclase phenocrysts up to 0.5 mm long are arranged in glomeroporphyritic groups, and are extensively altered to clay minerals and albite. Numerous small areas of antigorite enclosed by a frame-work of hematite are probably pseudomorphous after olivine. Many retain the bipyramidal form typical of euhedral olivine crystals.

The groundmass is composed of a network of plagioclase laths up to 0.3 mm long with interstitial areas composed of chlorite (after pyroxene?) and a turbid brown material which is probably hematite-charged K-feldspar representing devitrified glass.

The amygdales have a maximum diameter of 5.0 mm and although not always spherical, are rounded in shape. They are lined by a narrow rim of chlorite and infilled with a colourless zeolite which has a radiating form.

Texturally this rock may be described as intersertal and amygdaloidal.

FINE-GRAINED BASALT

Hand specimen. These rocks are fine to medium-grained, grey and pinkish brown in colour and composed of an intermeshing network of plagioclase and pyroxene crystals with rare phenocrysts of plagioclase. The weathered surface is an orange-brown, somewhat hackly skin.

Thin-section. The plagioclase phenocrysts are subhedral and anhedral, and are twinned on Carlsbad and albite laws. They range between 1 mm and 3 mm in length, and are evenly and normally zoned from labradorite to andesine in all except one specimen in which they are zoned from bytownite to labradorite. Alteration is typically concentrated in the more calcic cores of the phenocrysts, and alteration products include sericite, carbonate, chlorite, zoisite, chalcedony and prehnite. Not all alteration products are developed in each rock specimen.

The plagioclase laths of the groundmass vary in length between 0.2 mm and 0.5 mm, and are not as well twinned as the phenocrysts. They are normally zoned from labradorite to andesine, and commonly the cores of these crystals are obscured by a mixture of the alteration products sericite, chlorite and minor carbonate.

Three pyroxenes occur in these rocks, augite, pigeonite and orthopyroxene. Augite and pigeonite are present in every thin-section examined, whereas the orthopyroxene was noted in only two of them. Typically pigeonite forms small anhedral grains with a $2V\gamma$ between 0° and 10°, and is often altered to a pale yellowish-green chlorite (bastite) particularly along the (001) cleavage. In some sections it is difficult to distinguish from augite, but as a group the pigeonite crystals are smaller and more common than the co-existing augite crystals. Augite forms anhedral grains which sub-ophitically enclose plagioclase laths (see Plate 29E). It is recognized by a moderate positive optic axial angle, and is sometimes twinned on (100). In one of the thin-sections examined the augite grains exhibited an 'hour-glass' structure which may be a type of zoning. Intense staining with hematite along cleavage and fracture planes is common, and patchy alteration to bastite occurs. The orthopyroxene crystals tend to occur as clusters of larger crystals in a poorly developed glomeroporphyritic texture. They are anhedral grains which sub-ophitically include plagioclase laths, and are free from alteration and iron-staining. They are distinguished by low birefringence, a negative optic axial angle, and parallel extinction.

In one of the slides a few skeletal frameworks of hematite infilled with a bright green chlorite were noted. These are very similar to the relict crystals common in the amygdaloidal basalts from Yowalga No. 2, and may also be pseudomorphs after olivine.

The interstitial areas of these rocks are composed of potassium feldspar (orthoclase?) intensely charged with hematite, and including crystallites of magnetite and acicular apatite crystals. The composition of the feldspar was checked by staining with sodium cobaltinitrate. This interstitial material may be the result of devitrification of a glass, or alternatively just the product of crystallization of residual magma trapped in the interstices between the earlier-crystallized plagioclase and pyroxene. Some of the interstitial areas are infilled with pale green chlorite, bright green chlorite (see Plate 30F), prehnite, and chalcedony or combinations of these. Several rounded areas of antigorite and chalcedony are probably weakly developed amygdales. However none of these specimens could be described as amygdaloidal.

Texturally these rocks may be described as mildly microporphyritic, and partly sub-ophitic and partly intergranular (see Plate 29D).

DISCUSSION

Yoder and Tilley (1962, p. 353) define the term 'tholeiite' in the following way. "Tholeitte in the strict sense has as essential minerals an augite or a subcalcic augite, plagioclase (near An_{50}), and iron oxides. Olivine is present in subordinate amounts or may be absent. Characteristically an interstitial vitreous acid residuum, commonly pigmented, is developed, often providing the intersertal texture of this rock type, or this residuum may be represented by a quartzo-feldspathic intergrowth. The critical feature in this definition is the nature of the pyroxene or pyroxenes which may consist of augite zoned to subcalcic augite with pigeonite, or hypersthene or both (Tilley, 1961)."

Wilkinson (1967) states that an essential and critical feature of tholeiites is the reaction relation between olivine and Ca-poor pyroxene, often indicated by pyroxene mantling olivine. Olivine when present in tholeiitic basalts typically occurs only as phenocrysts, which are not commonly zoned.

The residual glass may be altered to ferruginous chlorophaeite, and the abundance of zeolites, chlorophaeite, various hydrated silicates containing iron (chlorites, clay minerals, etc.), carbonates, and chalcedony testify to the activity of late magmatic solutions charged with silica, carbon dioxide, iron, soda, and lime (Túrner and Verhoogen, 1960).

The three suites of basaltic rocks described in this report, the Officer Volcanics, the Kulyong Volcanics and the Table Hill Volcanics, are petrographically very similar. All have a weakly

DESCRIPTION OF PHOTOMICROGRAPHS—PLATE 29

A. Tholeiitic basalt, Officer Volcanics, W.A., showing granular augite and pigeonite with intermeshing plagioclase laths arranged to form intergranular and sub-ophitic textures. The opaque grains are magnetite and hematite, and the interstitial areas are composed of hematite-impregnated K-feldspar.
Plane-polarized light, X45.

B. Tholeiitic amygdaloidal basalt, Officer Volcanics, W.A., showing irregularly-shaped amygdales infilled with chlorite (white) and a mixture of chlorite and muscovite (grey). The skeletal crystal (top right) is composed of magnetite, chlorite, and antigorite, and is thought to be pseudomorphous after olivine. The groundmass is an intermeshing network of altered plagioclase laths with interstitial hematite-impregnated K-feldspar (devitrified glass?) and scattered magnetite granules.
Plane-polarized light, X20.

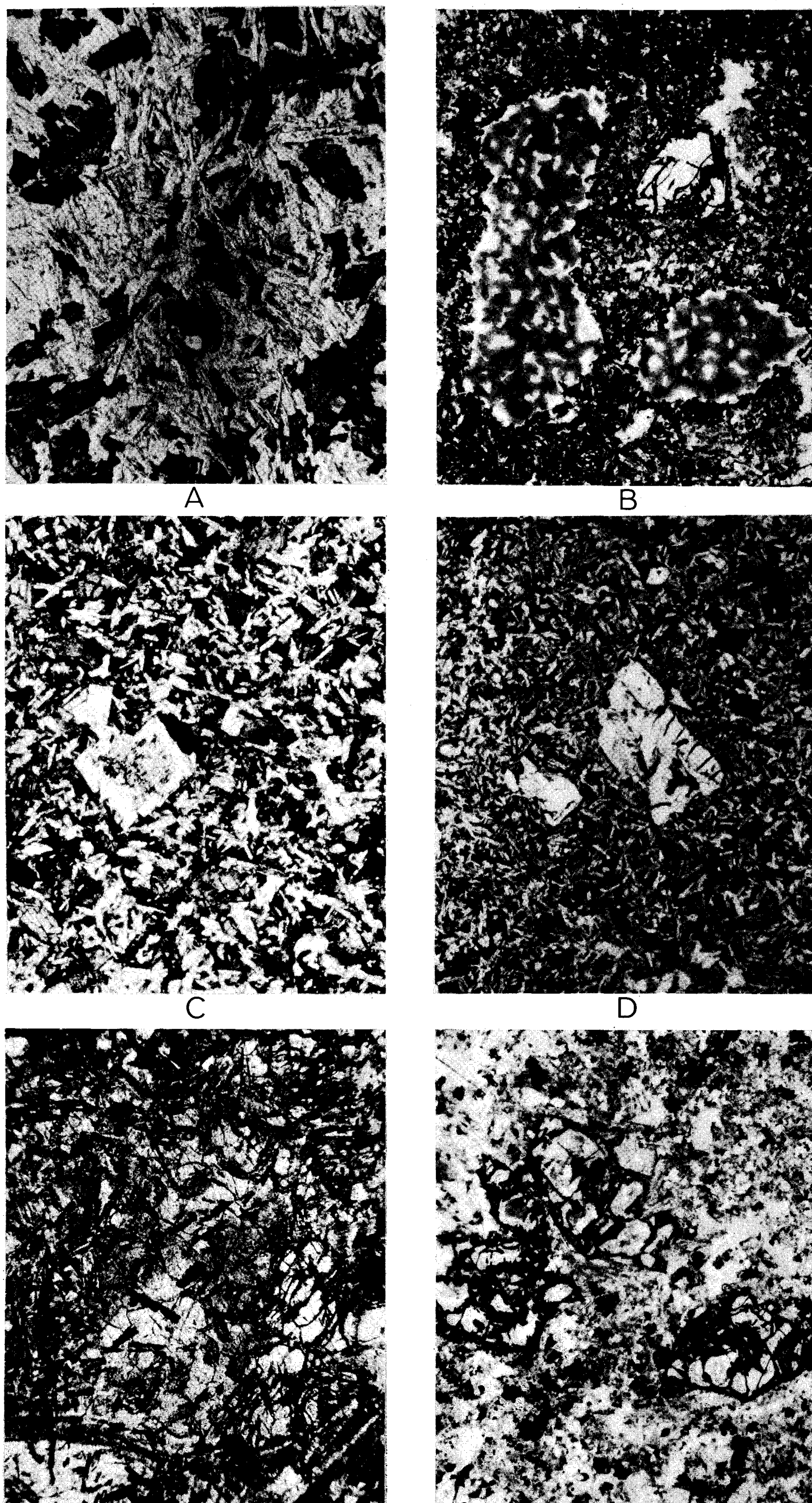
C. Tholeiitic basalt, Kulyong Volcanics, S.A., showing a subhedral microphenocryst of plagioclase which is slightly altered to K-feldspar, in a sub-ophitic and intersertal groundmass of plagioclase laths, granular augite, opaque magnetite or titanomagnetite, and interstitial hematite-impregnated K-feldspar (devitrified glass?).
Plane-polarized light, X20.

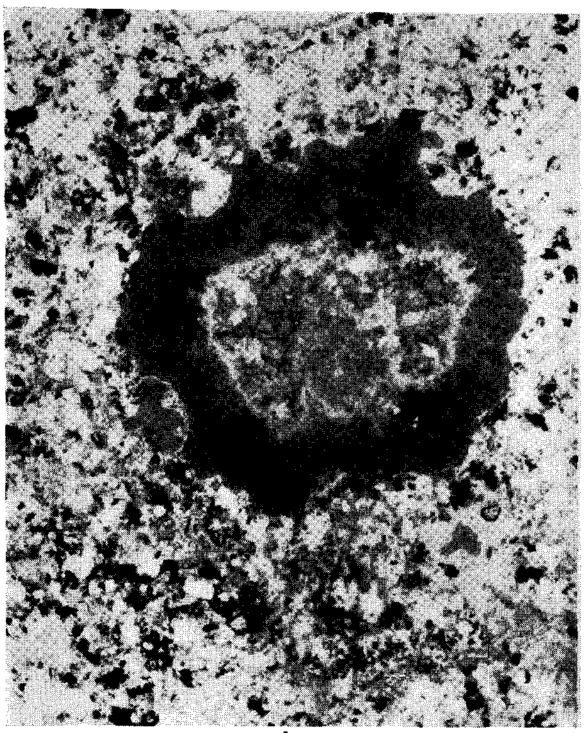
D. Tholeiitic basalt, Table Hill Volcanics, W.A., showing an anhedral microphenocryst of lightly sericitized plagioclase set in a sub-ophitic and intergranular matrix of plagioclase laths, granular augite and pigeonite, irregular magnetite and hematite grains, and interstitial hematite-impregnated K-feldspar (devitrified glass?).
Plane-polarized light, X20.

E. Tholeiitic basalt, Table Hill Volcanics, W.A., showing a large, anhedral, augite phenocryst, ophitically enclosing small laths of plagioclase and set in a groundmass of granular augite and pigeonite, plagioclase laths, and interstitial K-feldspar.
Plane-polarized light, X45.

F. Tholeiitic amygdaloidal basalt, Officer Volcanics, W.A., showing glomeroporphyritically arranged magnetite, chlorite, and antigorite pseudomorphs after olivine (?) in a fine-grained groundmass of altered plagioclase laths, interstitial chlorite and hematite-impregnated K-feldspar, and grains of magnetite.
Plane-polarized light, X20.

PLATE 29




A


B


C


D


E


F

DESCRIPTION OF PHOTOMICROGRAPHS—PLATE 30

A. Tholeiitic amygdaloidal basalt, Officer Volcanics, W.A., showing an irregular amygdale infilled with a mixture of muscovite and chorite (dark grey), muscovite (pale grey, radiating), and chlorite (pale grey, finely divided). The groundmass is composed of a mixture of altered plagioclase laths, magnetite grains, and hematite-impregnated K-feldspar.
Plane-polarized light, X20.

B. Tholeiitic amygdaloidal basalt, Officer Volcanics, W.A., showing an irregular amygdale infilled with chlorite (white at margin), a mixture of muscovite and showing an irregular amygdale infilled with chlorite radiating structure in centre of amygdale). The groundmass is made up of altered plagioclase laths, hematite-impregnated K-feldspar, and magnetite. Parts of several smaller amygdales are visible.
Plane-polarized light, X20.

C. Tholeiitic amygdaloidal basalt, Officer Volcanics, W.A., showing an irregular amygdale infilled with a mixture of muscovite and chlorite (dark grey) and muscovite (pale grey). The groundmass is composed of altered plagioclase laths, hematite-impregnated K-feldspar, magnetite grains, and olivine pseudomorphs.
Plane-polarized light, X20.

D. Tholeiitic basalt, Kulyong Volcanics, S.A., showing an irregular cavity infilled with colloform, fibrous silica, (either lussatite or chalcedony) with large grains of augite in a groundmass of plagioclase laths, granular pigeonite, and interstitial hematite-impregnated K-feldspar.
Plane-polarized light, X20.

E. Tholeiitic basalt, Kulyong Volcanics, S.A., showing interstitial areas infilled with chlorophaeite (dark grey) in a rock composed of plagioclase laths, granular augite and interstitial hematite-impregnated K-feldspar with minor chalcedony.
Plane-polarized light, X55.

F. Tholeiitic basalt, Table Hill Volcanics, W.A., showing irregular interstitial areas infilled by chlorite, in a rock composed of plagioclase laths, granular augite and pigeonite, interstitial hematite-impregnated K-feldspar, and scattered grains of magnetite.
Plane-polarized light, X45.

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developed microporphyritic texture with scattered phenocrysts of plagioclase zoned from labradorite to andesine, or bytownite to labradorite. The phenocrysts are set in an intermeshing network of plagioclase laths and pyroxene grains. Plagioclase in the groundmass is composed of labradorite zoned to andesine, with two exceptions where it is a little more calcic. In every specimen which was sufficiently unaltered for the pyroxenes to be identified, augite is present, either singly, or in association with pigeonite and/or an orthopyroxene. Possible pseudomorphs after phenocrystal olivine are present in both the Officer and Table Hill Volcanics. Anhedral grains of an opaque mineral (magnetite or titanomagnetite) are present in every thin-section examined.

The interstitial areas of all specimens are composed of partially devitrified glassy material, or an intensely pigmented (iron-stained) acid residuum which was identified positively in the Table Hill Volcanics as a potassium feldspar. Late-stage deuteric action is substantiated by scattered interstitial pockets infilled with chlorite, chalcedony, and prehnite. Chlorophaeite fills scattered pockets in the Kulyong Volcanics.

Amygdaloidal basalts occur in each of the Officer Volcanics, Kulyong Volcanics and Table Hill Volcanics. The amygdaloidal basalts from the Officer Volcanics and Table Hill Volcanics are very similar. Unfortunately none of the vesicular basalt from the Kulyong Volcanics has been described.

Clearly then these three groups of basaltic rocks all belong to the tholeiitic magma suite. Although petrographic resemblance alone cannot prove their contemporaneity there is sufficient similarity for further evidence on this point to be sought, and for interpretation of the available evidence to be examined. The most pertinent data available for reinterpretation are the isotopic analyses of the Officer and the Kulyong Volcanics.

The Officer Volcanics have been dated by both the Rb/Sr and K/Ar methods. Using the Rb/Sr method, Bofinger (*in* Jackson, 1966) found that the three samples taken between 2,417 and 2,419 feet defined an isochron at 446 m.y. with an initial Sr^{87}/Sr^{86} ratio of 0.7136. Bofinger interprets this as a 'metamorphic' age for three reasons. Firstly, all samples show alteration, and loss of radiogenic Sr^{87} is considered by him to be a distinct possibility; but there is no proof that this has in fact occurred. Secondly, vesicles constitute about 50 per cent of the volume of the rock and Bofinger considers these to have been infilled some time after the consolidation of the basalt, with consequent interference in the apparent age obtained; but infilling of vesicles is almost certainly a deuteric process which would have taken place during the closing stages of crystallization of the basalt. Thirdly, Bofinger considers the high initial Sr^{87}/Sr^{86} value of 0.7136 to be unlikely for an olivine basalt, since these normally have a low and constant initial Sr^{87}/Sr^{86} value of about 0.702. On this evidence he rejects 446 m.y. as the age of crystallization. His preference for a minimum crystallization age of 1,000 m.y. was obtained by assuming an initial Sr^{87}/Sr^{86} value of 0.702 and using only the least altered sample. An age of 1,143 m.y. for a core from 2,760 feet depth would follow from the same assumption. However, the Officer Volcanics are tholeiitic rather than olivine basalts, and a comparison of the initial Sr^{87}/Sr^{86} values of other tholeiitic rocks indicates that there is little justification for assuming an initial Sr^{87}/Sr^{86} ratio of 0.702. Compston, McDougall and Heier (1968, p. 133) found tholeiitic sills from Antarctica to have initial Sr^{87}/Sr^{86} ratios closely comparable with the indicated 0.7136 of the Officer Volcanics isochron.

K/Ar dates for core from 2,760 feet gave ages of 445 m.y. (Isotopes, Inc.) and 447 m.y. (Geochron). This fits very well with the Rb/Sr and age of 446 m.y. for core between 2,417 and 2,419 feet. The two K/Ar dates for core from 2,422 feet, 357 m.y. (Geochron) and 331 m.y. (Isotopes Inc.) appear to be anomalous and are probably due to argon leakage. K/Ar isotopic ages of the Kulyong Volcanics gave results of 475 $\pm$ 20 m.y. and 485 $\pm$ 20 m.y. The simplest interpretation of all available petrographic and isotopic evidence is that the Officer Volcanics, Table Hill Volcanics, and Kulyong Volcanics are probably all of Ordovician age.

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DIVISION V

School of Mines, Western Australia Annual Report — 1968

The Under Secretary for Mines:

I submit for the information of the Honourable, the Minister for Mines my report for 1968. The report refers to Kalgoorlie and to Norseman.

KALGOORLIE

Enrolments

The number of enrolments was 297, an increase of 19 on the previous year. Class enrolments increased by 187 to 988. Details of enrolments are supplied in Tables I and II. Enrolment distributions and trends over the last five years are shown in Table III.

Revenue

The revenue for the year totalled $15,114 an increase of $358 on the previous year. The moneys received included $2,000 paid into the Apparatus and Equipment Trust Fund by the Chamber of Mines. A detailed statement is given in Table IV.

Courses of Study

The first years of the new Associateship Courses were introduced. The previously existing courses were retained for third and fourth year students. In 1968 the first two years of the new courses were taught: the old Courses will be phased out by 1970.

The new Senior Certificate Course became effective in 1968.

The Chamber of Mines agreed to grant Day Release to School of Mines students in 1968 and this materially assisted in accelerating the development of students in courses.

Examinations

The results of the Annual Examinations are summarized in Tables VI and disclose no significant variation from those of previous years.

Diplomas and Certificates

Details of Diplomas and Certificates granted are set out in Table VII.

Library

The number of items catalogued at December 31st 1968 was 1109. There were 83 requests to borrow by inter-library loan and 11 requests to lend.

The library has been able to increase its services by the appointment of a full-time Librarian. It is hoped that a further increase in services offered will be made when the library becomes centralised and moves into the new building.

Many projects have been put forward due to the increased staff time. These include cataloguing and numbering of uncatalogued periodicals in several departments, tidying up of shelves and so on.

Services to the Public

The School provided the usual services to industry and to the public in addition to its teaching activities. The number of samples submitted for free assay and determination totalled 520.

Advisory Committee and Apparatus and Equipment Trust Fund

The Advisory Committee met 8 times. No additional items were authorized during the year. However, items already authorized but available only on long term order were proceeded with.

Kalgoorlie Metallurgical Laboratory

See Appendix 2.

Students' Association

The President of the Students' Association was Mr. I. C. Field. The usual activities of the Association were carried out and once again the profits from the Annual Ball were donated to the Slow Learners Group in Boulder. Congratulations are extended to those students who were successful in the Annual Examinations and particularly to those who completed courses.

NORSEMAN

Enrolments

See Table III.

Revenue

See Table IV.

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.

J. DOUGLAS COLLISTER,
Acting Director, School of Mines.

March 25, 1969.

Table I

ENROLMENTS, 1964-1968

Year	Kalgoorlie		Norseman	
	Individual	Class	Individual	Class
1964	329	830	59	128
1965	275	858	50	122
1966	240	775	51	122
1967	278	801	50	124
1968	297	988	46	109

Table II
CLASS ENROLMENTS, 1968

Subject	Kalgoorlie	Norseman
Chemistry P	27	....
Chemistry Q	16	5
Chemistry 10	17	....
Chemistry 2	3	....
Analytical Chemistry 10	6	....
Analytical Chemistry 2	4	....
Metallurgy A	2	7
Metallurgy 10	11	....
Mineral Dressing 20	2	....
Mineral Dressing 3	1	....
Chemical Metallurgy 2	2	....
Physical Metallurgy 20	1	....
Physical Metallurgy 2	2	....
Mathematics P	27	7
Mathematics Q	74	1
Mathematics QS	5	....
Mathematics 11	62	6
Mathematics 12	36	....
Mathematics 21	10	....
Mathematics 22	9	....
Physics Q	58	5
Physics 11	39	....
Physics 12	28	....
Physics 200	2	....
Electronics 10	15	....
Drawing P	27	6
Drawing Q	33	1
Drawing 11	32	1
Materials Science 13	10	....
Applied Thermodynamics 15	7	....
Applied Thermodynamics 20	7	....
Electrical Technology 12	15	....
Electrical Engineering 20	5	....
Electrical Engineering 2.1....	9	....
Electrical Engineering 2.2....	8	....
Strength of Materials 14	8	....
Structural Engineering 20	8	....
Structural Engineering 2.1	8	....
Structural Engineering 2.2	6	....
Workshop Technology 11	7	....
Workshop Technology 12	6	....

Table II—*continued*
CLASS ENROLMENTS 1968,—*continued*

Subject	Kalgoorlie	Norseman
Theory of Machines 20	4	....
Machine Design 1.2	4	....
Fluid Mechanics 20	6	....
Internal Combustion Engines	9	....
Geology 13	34	....
Geology 12	20	....
Geology 11	20	....
Geology 21	15	....
Geology 221	2	....
Geology 231	12	....
Geology 232	11	....
Geology 31	2	....
Geology 33	2	....
Mining A	11	....
Mining B	2	2
Mining 10	28	9
Mining 2.1	6	....
Mining 2.2	1	....
Mining 3	9	....
Mine Ventilation 10	2	....
Surveying A	1	....
Surveying 10....	20	....
Surveying 2.1	11	5
Surveying 2.2	6	1
Cartography 10	23	9
English P	8	5
English Q	11	....
English 10	25	....
English 20	6	....
English 1	17	....
Electrical Theory A	....	5
Electrical Theory C....	....	3
Welding A	....	9
Welding B	....	9
Workshop Practice B	....	7
Drawing W	....	2
Electrical Drawing A	....	2
Electrical Drawing B	....	2
Totals	988	109

Table III
NUMBER OF STUDENTS ENROLLED FOR VARIOUS COURSES

Courses	Kalgoorlie					Norseman				
	1964	1965	1966	1967	1968	1964	1965	1966	1967	1968
ASSOCIATESHIP COURSES—										
Mining....	31	19	21	20	35	3	1	....	....	....
Metallurgy	20	19	19	19	20	....	....	....	....	....
Engineering	43	31	25	27	25	....	....	....	....	....
Mining Geology	7	7	8	10	14	....	....	....	....	....
Total	101	76	73	76	94	3	1	....	....	....
CERTIFICATE COURSES—										
Mine Surveyors	27	30	25	28	36	9	10	11	12	9
Engineering Draughtsman	29	24	18	18	9	....	3	....	1	....
Assayers	8	4	3	....	....	....	....	....	....	....
Chemical Technician	....	....	....	3	3	....	....	....	....	....
Senior Certificate	....	....	....	....	11	....	....	....	....	....
Total	64	58	46	49	59	9	13	11	13	9
TECHNICIAN COURSES—										
Workshop (Electrical)	....	....	....	....	....	....	5	6	5	8
Welding	19	11	14	4	....	6	4	6	6	9
Workshop (Mechanical)	....	....	....	....	....	1	20	12	15	8
Mine Managers (2nd class)....	8	7	5	6	5	1	2	2	....	1
Total	27	18	19	10	5	8	31	26	26	26
NO SET COURSE—										
Preparatory Subjects	17	26	29	53	18	....	3	7	3	....
Qualifying Subjects	17	16	7	18	20	....	....	3	....	....
External Students	2	....	....	....	2	....	....	....	....	....
Junior and Leaving	18	7	1	9	....	....	....	....	....	....
University	1	2	....	1	....	....	....	....	....	....
Others	82	72	65	62	99	39	2	4	8	11
Total	137	123	102	143	139	39	5	14	11	11
TOTAL FOR YEAR	329	275	240	278	297	59	50	51	50	46

Table IV
REVENUE, 1966-1968

	Kalgoorlie			Norseman		
	1966	1967	1968	1966	1967	1968
	$	$	$	$	$	$
Class Fees	2,532.05	2,705.20	4,334.70	447.20	306.50	413.90
Lecture Notes	85.50	101.75	114.00	16.75	14.50	15.75
Laboratory Deposits	182.00	236.00	244.00	20.00	....	16.00
Supplementary Examinations	46.00	34.00	44.00	2.00	....	2.00
Apparatus and Equipment Trust Fund	4,000.00	2,000.00	2,000.00	....	....	....
Metallurgical Laboratory Trust Fund	1,835.55	1,759.55	1,017.00	....	....	....
Commonwealth Grants—Research Laboratory—Trust Fund	3,060.00	6,200.00	6,450.00	....	....	....
Students' Association	320.50	366.50	628.00	....	....	....
Mine Managers and Underground Supervisors	86.10	62.90	70.30	....	....	....
Sundries	273.10	1,290.40	212.70	....	....	....
Total	$12,420.80	$14,756.30	$15,114.70	$485.95	$321.00	$447.65

Table V

NUMBER OF STUDENTS PAYING FEES 1966-1968

Group No.	Description	Kalgoorlie						Norseman					
		1966	1967	1968				1966	1967	1968			
		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	63	68	7	52	....	59	17	24	....	13	....	13
2	Students 18–20. Class fees and other fees as for Group 1	65	70	17	68	....	85	15	12	....	14	....	14
3	Students 21 and over. Class fees and other fees as for Group 1	95	123	6	125	2	133	19	14	....	19	....	19
4	Returned Servicemen. Exempt Class fees	2	2	....	3	....	3	....	....	....	....	....	....
5	Staff. Exempt class fees	13	12	....	12	....	12	....	....	....	....	....	....
6	Scholarship Holders. Exempt class fees	2	3	5	....	....	5	....	....	....	....	....	....
		240	278	....	....	....	297	51	50	....	....	....	46

Table VI

RESULTS OF ANNUAL AND OF SUPPLEMENTARY EXAMINATIONS BASED ON CLASS ENROLMENTS, 1964-1968

	Kalgoorlie					Norseman				
	1964	1965	1966	1967	1968	1964	1965	1966	1967	1968
Class Enrolments = A	827	858	775	801	939	115	122	122	124	109
Number of entries for Annual Examinations = B	581	558	426	534	674	97	82	92	72	66
B/A per cent.	70	65	55	67	72	84	67	75	58	61
Number of passes at Annual Examinations as a per cent. of A	53	53	51	49	57	75	55	60	40	55
Number of passes at Annual Examinations as a per cent. of B	75	81	93	73	80	89	82	79	69	91
Number of passes at Annual Examinations and Supplementary Examinations as a per cent. of A	57	54	53	51	59	75	56	61	41	55
Number of passes at Annual Examinations and Supplementary Examinations as a per cent. of B	81	82	95	76	82	89	83	80	71	91

Table VII

COURSES COMPLETED 1964-1968 KALGOORLIE AND NORSEMAN

	1964	1965	1966	1967	1968
Associateship Courses—					
Mining	10	4	4	4	1
Metallurgy	2	2	5	2	2
Engineering	8	6	5	3	2
Mining Geology....	....	3	2	....	1
	20	15	16	9	6
Certificate Courses—					
Assayers	6	4	4	3	1
Mine Managers	4	1	....	....	....
Mine Surveyors	3	10	1	4	4
Engineering Draughtsman	8	6	7	1	1
Senior Certificate	....	....	....	....	10
	21	21	12	8	16
Technician Courses—					
Mine Managers (2nd Class)	1	2	2	....	....
Welding	3	1	1	....	1
	4	3	3	....	1

APPENDIX 1

ASSOCIATESHIPS COMPLETED—1968

Metallurgy

Tillotson, D. L.
Dunstan, P. L.

Mining Engineering

Patterson, B. S.

Engineering

Dombrose, J. S.
Ruvidini, A.

Mining Geology

Fradd, J. F.

APPENDIX 2

KALGOORLIE METALLURGICAL LABORATORY

By E. Tasker, A.W.A.S.M. (Met.), A.M.Aus., I.M.M., Senior Research Metallurgist

INTRODUCTION

Five reports of investigations and two hundred and seven certificates of testing or anlysis 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, 3002,
Victoria,

from whom copies of the reports can be obtained usually six months after date of issue.

In addition to the reports issued, one other investigation was approved and test-work was in progress.

COMPLETED INVESTIGATIONS

Report No. 745

Gravity, magnetic and electrostatic separations were carried out on a titaniferous-iron sand from near Onslow, Western Australia.

Report No. 746

Gravity concentration tests were carried out on a cassiterite bearing eluvium from Moolyella near Marble Bar, Western Australia.

Report No. 747

Flotation tests were carried out on a kyanite ore from Chittering, Western Australia.

Report No. 748

Test-work was carried out on a limonitic iron ore from the Jurien Bay area of Western Australia.

Report No. 749

Flotation tests were carried out on a fluorite ore from Cookes Creek, via Nullagine Western Australia.

INCOMPLETE INVESTIGATIONS

Report No. 750

Test-work was in progress on a pyritic gold concentrate from Fimiston, Western Australia.

Kalgoorlie Metallurgical Laboratory

SUMMARY OF YEAR'S WORK, 1968

Report Number	Owner	State	Locality	Ore Type	Type of Investigations	Confidential Until	Number of Metallurgical Tests	Number of Assays	
								Gold	Other
745	J. L. Lewis, Perth	W.A.	Onslow	Titaniferous-iron Beach Sands	Concentration	8/9/68	13	....	82
746	J. T. Eddy, Perth	W.A.	Marble Bar....	Tin	Concentration	10/10/68	7	....	7
747	Mineral Equipment Co. Pty. Ltd., Bentley	W.A.	Chittering	Kyanite	Concentration	23/1/70	17	....	30
748	J. A. Mazza, Perth	W.A.	Jurien Bay	Iron	Beneficiation	7/4/69	26	....	114
749	R. Butler, Rivervale	W.A.	Nullagine	Flourite	Beneficiation	25/5/69	16	....	19
....	Certificate Nos. 3757 to 3809, 3811 to 3929, 3931 to 3965	....	....	....	....	....	....	531	543
....	Free Assays	....	....	....	....	....	....	106	372
						Total	79	637	1,167

The following investigations were incomplete or pending at December 31, 1968 :—

Report Number	Owner	State	Locality	Ore Type	Type of Investigations	Confidential Until	Number of Metallurgical Tests	Gold	Other
743	Western Mining Corporation, Kalgoorlie	W.A.	Londonderry	Lithium pegmatite	Concentration	....	20	....	60
750	Gold Mines of Kalgoorlie (Aust) Ltd, Fimiston	W.A.	Fimiston	Gold	Recovery	....	5	....	15
						Total	104	637	1,242

DIVISION VI

Annual Report of the Inspection of Machinery Branch of the Mines Department for the Year 1968

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 31st December, 1968.

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 lb. to the square inch, and having a capacity exceeding five cubic feet; but does not include containers used for transport;

(c) any vessel used under steam pressure as a digester; and

(d) any steam jacketed vessel used under steam for boiling, heating, or disinfection purposes.

It also includes the setting, smoke stack, and all fittings and mountings, steam or other pipes; feed pumps and injectors and other equipment necessary to maintain the safety of the boiler.

Return No. 1.

In this return is recorded the number of boilers of the various types added to our registrations during the year. Those of Western Australian origin exceed by 28 the number of imports. This shows a considerable reduction in the locally manufactured proportion compared with 1967 although there was a 15% overall increase in new boilers in 1968.

Return No. 2.

This return shows the number of each type and overall total in the register of useful boilers. The total shows an overall increase of 648 or approximately 6% of the total 3,111 were not in use.

Return No. 3.

This contains a summary of operations for the year.

Manufacture of boilers in this State for export to other Australian States shows a decrease of approximately 30% compared with 1967. Ninety three were sent to other Australian States and only three were sent outside Australia.

Imports into Western Australia from other States and Oveaseas increased remarkably, being approximately 40% and 160%, respectively.

The numbers of boilers exported from Western Australia once again are made up almost entirely of package boilers from one firm. Imports are generally in the same categories as last year, i.e. portable air receivers, engine starting air receivers and numerous L.P. gas and anhydrous ammonia vessels. The two latter types of vessels are made in large quantities to standard designs in the Eastern States so that there is no competition from Western Australian manufacturers. Added to this is the ever increasing use of both products throughout this State. In the imports from Overseas are many specialised vessels for use in the refinery fertilizer and gas complex and also in the nickel refinery.

This year saw the official opening of the blast furnace at Australian Iron & Steel, Kwinana, the continued expansion of the alumina refinery and the petroleum-fertilizer complex, also in the Kwinana area. Work proceeded with the new powerhouse for the State Electricity Commission at Kwinana and the fourth unit was completed at Muja. A start was made on the nickel refinery. The foregoing are major industries but the increase also continued in medium and small installations. Mining and prospecting, particularly in the nickel and iron ore fields continues unabated and machinery complexes for several salt producers are almost completed.

MAINTENANCE AND MISCELLANEOUS

Again this year the general standard of operation and maintenance has been satisfactory.

As has been previously reported insufficient inspections are being made under working conditions due to lack of staff. I consider this is a most necessary function of the Branch which is invaluable to owners, operators and ourselves in furthering safe practices in the operation of boilers.

Manufacture of boilers and pressure vessels in this State has maintained the usual high standard expected with few exceptions. The new constructor breaking into the pressure vessel field generally has difficulties, particularly if it is Class I or II where a number of tests before, during and after manufacture are required. The Branch still has to endure the manufacturer, his supervisors and tradesmen who do not make good known deficiencies in fabrication but wait for the Statutory Inspector to find them and order repairs. If the Inspector happens to miss the fault it is not rectified. This attitude is deplored.

The amount of time spent checking the various facets of pressure welding has increased markedly this year. This has been brought about by increases in the numbers of large high pressure and temperature water tube boilers and steam lines being installed in Western Australia and also by much closer attention being given to approval of methods, procedure qualification of welders, site inspections and checking of radiographs. This has not had the attention it warranted previously and, although hard pressed for staff, it was felt we had to give more attention to this important work. Unfortunately this has only been done at the expense of other functions of the Branch.

SECTION 2

EXPLOSIONS AND INTERESTING DEFECTS

I am pleased to be able to report that there was only one explosion of a boiler or pressure vessel this year and fortunately no person was injured.

The vessel in question is an autoclave approximately 46 ft. long by 6 ft. 6 in. diameter, allowable working pressure 210 p.s.i., used for curing bricks. A door and frame of the castellated locking type at one end gave access to the vessel.

The vessel had been filled with bricks for curing and the door closed and racked into position by the boiler attendant, who had been employed for a number of years, in the presence of the plant engineer who was new to the job but had experience of this type of autoclave elsewhere. Steam was then admitted to the vessel and inspection of the steam chart after the mishap showed a rise in pressure to 65 p.s.i. from 3.30 p.m. to 4.15 p.m. when the explosion occurred. The door blew out and was projected 50 yards being stopped by a pile of bricks. The vessel was projected 19 ft. in the opposite direction being stopped by a pile of sand which it penetrated to a depth of 8 ft.

Investigations revealed angled drag marks on the door castellations indicating they had probably torn across the mating castellations of the door frame. The door was also twisted and ⅜ in. out of round.

The Inspector who carried out the investigation is of the opinion that the door interlock was not functioning properly and the door castellations were only partially engaged in the mating castellations in the door frame when steam was admitted. This partial engagement was sufficient to hold until the pressure rose.

It was not possible to prove after the accident that the interlocking gear was inoperative but a check of two similar autoclaves in the same premises revealed that the gear was inoperative on both vessels.

INTERESTING DEFECTS

Most of the defects encountered this year have been run of the mill and the following report is noteworthy only because it shows some variation of the many ways in which a boiler can become short of water.

The boiler in question was a small cylindrical multitubular underfired fitted with a float control. The float control was connected to the feed pump and a low water alarm bell. It was not connected to the oil fuel supply. The feed pump drew its water from a float controlled tank. A low water condition occurred which resulted in all the tubes pulling out of their expansions in the back tube plate. Fortunately nobody was injured. Further investigation revealed that the back tube plate was severely bulged and the boiler shell, where exposed to flame, had also bulged over full length and approximately the bottom half.

Enquiries revealed that the low water alarm bell had failed to ring and the feed water supply tank had been found empty. The supply tank was empty because some person unknown had shut off the water to the float control valve. This was probably due to the control valve leaking badly resulting in the tank overflowing. The water level controller was found to have a broken conductor in the bell circuit.

The foregoing incident is yet another example which serves to illustrate the following points, all of which have been emphasised many times by all Statutory Authorities and the S.A.A. Boiler Committee:—

(1) The fallacy of blind faith in automatic and semi-automatic controls.

(2) The failure to check water levels by conventional visual and manual methods.

(3) Lack of routine and preventive maintenance resulting in the feed tank float control valve being in poor condition.

(4) Failure to check automatic controls and alarms at short intervals to prove reliability.

SECTION 3

INSPECTION OF MACHINERY

(See Returns Nos. 4, 5 and 6)

At the end of the year 61,111 groups of machinery were registered, an increase of 4,542 groups compared with 1967. Of this total number of groups once again almost 40% were *NOT* inspected during the year for the same reason as last year, i.e. shortage of staff. The disheartening story of inspections not carried out continues in the specialised fields of lifts and escalators and cranes. With the phenomenal increase in multi-storey office blocks, flats and home units, new lift and escalator installations registered totalled 123, an increase of almost 14%, during the year giving a total of 990 registered. The checking of design submissions and then the inspection and testing of the new installations has been maintained quite well but only at the expense of existing installations, the largest percentage of which have not been inspected for years. New installations finally inspected, tested and certificated, which generally require several visits each, numbered 74.

The story in the crane field is painfully similar. Industrial expansion and large construction projects have continued causing the numbers of cranes of various types to continue the upward trend which has been in evidence for several years. Again design checking and inspection and testing of new designs and installations has been kept reasonably up to date although some overtime has been required to reduce the back log of submissions awaiting checking. However lack of staff has not permitted more than a token number of annual inspections being carried out after initial registration is completed. The most alarming feature of the constant pressure when checking designs is that insufficient time is available for calm appraisal and consideration of all facets and implications. This leads to the fear that a disastrous mistake could be made due to rushing the job. Unfortunately a very real and worrying possibility.

For the first time for many years a major innovation in the winding engine field was submitted for consideration. This was a departure from the forms of braking which have been in use utilising post or band brakes either dead weight or foot applied through mechanical linkages. The new type brakes are called unit brakes and are multi-spring applied, hydraulic power release. It is claimed that adjustment, operation and efficiency is greatly improved. The system has been successfully used in the United Kingdom. Approval of the new system necessitates amendments to the regulations relating to winding engines.

ACCIDENTS TO MACHINERY

Mobile cranes again have featured in a number of accidents. One mishap which will be detailed revealed a number of unsatisfactory features which contributed to the accident and which are all too common in the field of mobile crane operation. Fortunately no person was injured but the jib was badly damaged.

The investigating Inspector reports as follows:—

"At the time of the accident the crane was lifting four pieces of 8" dia. piping 19' 9" long —total weight approximately 2100 lb. The load was being picked up over the rear of the crane and slewed to the side. The crane was not blocked and was rigged with 80 feet of main jib.

"The crane driver says he thought the crane jib was at an angle of 65° (from the angle indicator) but considers now that he probably made a mistake and had the jib at 55°.

"This mistake was undoubtedly the primary cause of the accident as the appropriate load chart gives loads for this crane in the unlocked condition of:—

Angle	Over side (lb.)	Over rear (lb.)
55°	1800	2900
65°	3700 approx.	5600 approx.

"In the unblocked condition stability of these cranes is based on 75% of tipping (contrary to Code requirements). Thus theoretically the crane will tip over the side with jib at an angle of 55° with a load of $1800 \times 1.33 = 2400$ lb.

"The single sheave hook block for this model crane weights 300 lb. which brings the crane to tipping with the given SWL on the hook. In fact, the two sheave block was reeved and this weighs 600 lb., thus the SWL was in fact not 1800 lb. but 1200 lb.

"While this investigation shows that undoubtedly the crane driver's error caused the accident, it also brings to light several very unsatisfactory and dangerous elements in working cranes to the present load chart.

"When working the crane without outriggers it is necessary to first read the angle of the jib on the angle indicator, then find this angle adjacent to the appropriate jib length on the "with outriggers" tabulation, read the jib *radius* corresponding to this angle and then transfer this radius to the "without outriggers" tabulation. It is then necessary to make appropriate adjustments to the SWL thus found, for weight of hook, hoist rope, slings, fly, if fitted, etc.

"It is contended that this procedure is far too complicated for the average crane driver to do with any degree of confidence. The factors of safety involved are so small, when reasonably long jibs are employed, that a considerable danger of turning the crane over is involved even with comparatively small loads.

"Another dubious point in working these cranes is, in my opinion, the jib angle indicator. It is easy to read say 65° when the jib is actually at 55° because only a pointer is provided, and obviously the mistake is easily made. This could be rectified by replacing the pointer with a plate which covered the high figures.

"Another point that is rather contentious, is the insistence of manufacturers to provide one list of loads that may be picked up over the rear of the crane, and another list for loads that may be picked up over the side, the lists being in juxtaposition. It would be a step in the right direction to make one separate section of the load chart for slewing ratings and another separate section for maximum ratings over the rear of the crane.

"The slewing of a load that could be picked up over the rear was one of the causes of this accident, despite the fact that the crane driver had made other mistakes before this."

This report concerns a winding engine and although it can hardly be classed as a machinery accident there was damage to the machine and the circumstances although not unique may serve as a warning to other owners and users of winding engines.

This Department was notified that a winding engine drum had been found defective. When the tread plate was stripped off the cheek plates a crack approximately 4 ft. long was found in the tread plate landing of the cast iron cheek plate on the brake path side. The tread plate of mild steel ⅜"t. was found to be wavy with distortion to a maximum of 11/32".

A temporary repair was effected to enable the machine to be put into use at reduced loadings until new and heavier cheek plates and tread plates could be procured.

The investigating Inspector considers the collapsing of the tread plate and resultant cracking of the landing had been in progress for some time. This winder was first put into service in 1930 and transferred to its present location in 1952. The life story of the machine is typical of a number of winders on the goldfields and the same resultant defects have appeared before. The history is one of continuous work on ore haulage with increasing loads and depths, eventually leading to cracking through overloading.

During 1968 an earthquake was experienced in Western Australia. Reports of damage within the ambit of this Branch were confined to three lifts, fortunately without injury to persons. The investigating Inspector reported as follows:—

"Damage to lift installations caused by earthquake damage in the city area was confined to three lifts which due to counterweight rail displacement had their counterweights forced out of the guide rails:

(i) The counterweight landed on a bracket while the car was in the up direction causing the ropes to slip in the sheave. Both ropes and sheave were excessively heated by the resultant friction and replacement was considered necessary.

(ii) The counterweight smashed into the top of the car while the latter was in the up direction. The speed on impact was 1000 f.p.m. and fortunately little damage was done. No one was injured.

(iii) The counterweight smashed into the bottom of the car while the latter was in the down direction. The speed on impact was 600 f.p.m. Damage in this case to the underside of the car platform frame was considerable. No one was injured."

SECTION 5.

ACCIDENTS TO PERSONS

Returns 7 and 7a record accidents to persons in which machinery subject to the Act was involved. The former relates to those of a serious nature, the latter to accidents classified as minor.

Return 7b shows accidents caused by machinery not subject to registration by this Department but investigated under the provisions of Section 50 of the Act.

During the year seven (7) fatalities occurred involving, mobile cranes (2), an overhead crane, an excavator, a conveyor belt, a winding engine and a set of rolls. A number of serious accidents occurred again on woodworking machines and metal stamping presses. Materials handling machinery, amusement machinery and mincers were also involved in injury to persons. This year saw a spectacular collision on a private railway which resulted in three people being injured, fortunately without permanent disablement. The material damage was both extensive and costly.

CASE "A"

This fatality concerns a mobile crane which was being used in the assembly of a mobile drilling machine used in the mining industry. At the time of the accident the lattice tower of the above machine was being lifted preparatory to replacing it on the machine. The tower was approximately 40 ft. long and had been slung by use of two wire rope slings. One sling was reeved and snottered through the tower and the other eye placed over the crane hook. The other sling was passed through the tower members and both eyes were placed on the hook. The angle formed by the slings at the hook has been checked at between 130° and 140°. The tower was raised and it is believed, due to points at which the slings were attached, only one end came off the ground. When it was approximately five to six feet off the ground the victim decided to move to the other side of the tower and proceeded to walk under the load. As he was directly under it one of the sling eyes slipped off the hook and the load fell crushing him underneath with fatal results. Two factors are noted as leading to this mishap. Firstly, the method of slinging which did not ensure that the slings could not become detached from the hook. Secondly, the victim placed himself in jeopardy by disobeying the cardinal rule "Never walk under a load". The moral is self evident and requires no elaboration on my part.

CASE "B"

This related to a mobile crane and again resulted in the death of the injured person. At the time of the accident the jib was being lengthened from the basic 30 ft. butt and head sections to 50 ft. The method of lengthening was as follows.

The two inserts, which were already pinned together, were lifted by the crane onto the tray of a semi-trailer truck and left with one end protruding over the back of the truck tray. The crane jib head was then lowered onto the truck tray adjacent to the inserts. The bridle spreader was lowered into the butt section of the jib and the pendant ropes removed. The bridle spreader was then connected to the butt, by means of a "load binder" chain obtained from the truck.

The bight of the chain was passed under the top clevises at the end of the butt and around pins in the bridle spreader intended for the jib pendant ropes, the end of the chain being secured by means of one of the binder clips.

The head and butt were then disconnected by removing the four connecting clevis pins. This left only the butt attached to the crane and supported by the luffing bridle via the load binder chain. The butt was then positioned behind the inserts which were already lying on the truck tray. Clevis pins were inserted, attaching the butt to the inserts which were lifted from the tray, the weight being supported by the load binder chain. The clevises on the end insert were manoeuvred into position behind the jib head. The victim was standing on the left hand side of the jib and the yard supervisor on the right hand side, ready to insert the clevis pins. The deceased apparently got partly beneath the jib to insert one of the pins on his side when the load binder chain broke allowing the jib to fall on him.

The method of lengthening the jib is commonly used and is quite acceptable. The means by which the bridle spreader was attached to the top of the butt section was not standard as the bridle fixing had been modified so that the bridle was usually attached to the butt with a long pin. On this occasion the pin was unserviceable and the chain was substituted.

A section of chain was tested and gave breaking strains such that the load imposed in the jib lengthening operation above would have been in excess of the S.W.L. but would have been well below the breaking load. It can only be concluded that the link that failed was faulty.

The clevis pins on this crane had been modified so that when breaking down the jib the pins could be removed from outside, i.e. the pin heads were inside. This was considered good practice as accidents have occurred when the pins were the other way round and it was necessary for the person dismantling to get under the jib to knock the pins out. When the pins came out the jib could jack knife and collapse on the dismantler. It was not envisaged that there would be collapse when assembling and therefore the heads being inside the pins were driven in from that side. Unfortunately this caused the victim to be under the jib to insert them.

Once again this accident points out the risks of being underneath any suspended load.

CASE "C"

This accident also resulted in the death of the injured person and occurred when an excavator was being assembled after repairs to a crack in the dipper handle. To make the repairs the bucket (or dipper) and dipper handle had been removed and the bucket detached from the handle. When the repairs had been completed the dipper handle was lifted by the hoist block of the excavator and positioned so that the top end was resting on the shipper shaft drum near the saddle between the fork of the booms. The other, or bucket (dipper) end which is heavier was resting on the ground. The bucket was standing on the ground approximately 4-5 feet from a line through the end of the boom. The deceased was assisting with the re-assembly of the machine and at this time walked round and was standing between the boom and bucket.

It was found that the dipper arm was slightly out of line with the boom. In order to line it up the machine was slewed slightly with what was described as a jerking movement. This caused the end of the dipper arm to slip out of the boom and pivot on the heavy end resting on the ground. As the arm swung it caught the victim in the chest and crushed him against the bucket.

Several factors contributed to this fatality:—

(1) Method of assembly using the machine itself for hoisting. This is normal practice.

(2) Jerky operation of the slew. This was found to be due to a flow control needle valve not having been replaced in the slew air control system.

(3) The position of deceased during the operation. This is difficult to avoid as it is often difficult to pin point danger points under unusual conditions.

This mishap does emphasise the need for continual vigilance and awareness of hazards which may arise and also the need to keep machinery in good condition.

CASE "D"

This fatal accident occurred on a hand operated overhead crane which was situated in a bay adjacent to a pendant controlled electric overhead crane.

Some difficulty had been experienced with the travel of the hand operated crane and the victim, who was on the maintenance staff, and the maintenance fitter were investigating and eliminating the trouble which was in the attachment to the axle of one of the end carriage wheels nearest the other bay. The crane in the other bay had not been stopped and it appears deceased allowed his body to protrude across the other runway. The electric crane was travelled down the shop with the pendant control and caught the deceased between it and a column crushing him with fatal results.

I would like to note that another accident involving an overhead electric crane in which the circumstances were similar occurred during the year. Fortunately it was not fatal but there was severe injury.

This accident involved an electrician who was working on installations attached to building columns which also supported the crane runway. Again the crane was not shut down and as it moved down the shed the victim was caught by the end carriage, rolled round a column and dropped 3 feet onto a horizontal lattice truss which prevented him falling a considerable distance to the concrete floor.

Any comment that can be made on the two preceding accidents has been made on many occasions before but it is hoped that these two examples may emphasise the need for strict safety precautions where work on or about overhead cranes is undertaken.

CASE "E"

This fatality involved a conveyor belt installed in a passenger terminal. The belt was used for transporting luggage from the Customs Inspection points to a pick up point at ground level. At the time of the accident a migrant ship was berthed at the terminal and disembarkation procedures were in progress. The victim was a five year old child who was playing with a ball with his brother and sister while the parents were having their luggage checked by Customs. It appears that the ball rolled away from the children and under the luggage conveyor. Deceased was attempting to retrieve the ball by crawling under the conveyor when his arm was caught between the idler rollers and the returning bottom belt, pulling him in with fatal results.

The clearance between the conveyor side frame and the floor was approximately 8 in. and since the accident this gap has been closed in.

The arrangement of the machinery concerned in this accident is such that involvement of an adult was extremely unlikely. However it shows that where children are likely to be in the vicinity the installer must give extra consideration to safety and guarding, taking into account the size, activity, speed of movement and unawareness of children to the potential danger.

CASE "F"

This accident, again unfortunately resulting in the death of the victim, ocurred on a paper rewinding machine which is a series of rolls used to cut and roll paper to various diameters and widths. The operator stands near the finished product roll to which is fitted a nip guard consisting of a bar extending across the roll. The guard is spring loaded and so constructed that it maintains its position as the size of the roll of paper varies. Its function is to prevent the operator's fingers being caught between the pressure roll and the paper roll. Sometimes it is necessary for the operator to feel the paper on the roll to check the operation of the machine. The nip guard had been modified by the owners by the addition of a $\frac{3}{8}$ in. t. wooden batten to the bottom edge.

Just prior to the accident a disc cutter had not been functioning correctly causing the paper to overlap at this cut. The trouble had been rectified and the machine restarted. It is believed that the victim was probably checking the cut in the paper roll with his fingers when they were carried up to the nip guard. After the accident a considerable section of the wood attached to the nip guard was found to be broken away. Possibly the victim's hand hit the wood with considerable force breaking a section out thus allowing his fingers through. There was also some slackness in the mechanism keeping the guard on the periphery of the paper roll. Adding the clearance allowed by the piece of wood being broken out to the clearance allowed by the slackness and the total would be sufficient to pass a hand through to the nip point. Once the fingers entered the nip point the victim was pulled into the rolls. The nip guard being spring loaded was pushed up by the wedging action once the victim's arm was pulled under it and his body was drawn in with fatal results.

CASES "G" AND "H"

These two accidents are treated together as service lifts were involved in both cases. In the first case the lift was chain driven and served three floors. The drive consisted of a primary and secondary chain, the primary driving from the motor and gear box to the intermediate shaft, the secondary from the intermediate shaft sprocket to car connection and thence to the top of the lift shaft.

At the time of the mishap the gear box was being replaced. This necessitated removing the primary chain. So that this could be done it was necessary to lift the car away from the pit and secure it. This was done by fixing a sash clamp over the secondary chain at the intermediate shaft sprocket. The lift mechanic was in the pit and in removing the primary chain he dislodged the sash clamp allowing the car to fall. He instantly realised his danger and dropped to the floor but the car hit him on the head fracturing his skull and nose. A full recovery has been made.

The method of securing the car was palpably unsafe and reflects badly on a trained lift mechanic who should be more aware than most of the inherent danger involved.

The second service lift was wire rope suspended drum drive serving ground and first floors. A carton of books had been sent from the ground floor to the first floor. When the door was opened at the first floor it was found the carton had split and some books had jammed between the car and the shaft. Attempts to remove the jammed books by tugging at them were unsuccessful so it was decided to send the car down again to try to free them. The door was closed and the switches operated. It is not known how many times the switches were operated but when the door at the first floor was re-opened it was found that the books were still jammed. The victim then climbed up to the sill in order to get a better grip on the offending books. He had one foot on the sill and placed the other in the car. As his weight came onto the foot in the car the car fell away and trapped him with only head, right arm and shoulder protruding. It took several minutes to release the injured person and it was necessary to apply artificial respiration when he was freed. He suffered concussion, a lacerated jaw and injuries to his right arm and shoulder.

Several factors contributed to this accident:—

(1) The condition of the carton in which the books were to be transported.

(2) The fact that when attempts were made to lower the lift it was not realised that a slack hauling rope condition had been created.

(3) The placing of a person or part thereof in the lift car. Not permitted in service lifts.

(4) The failure to call expert assistance from people knowledgeable in lift operation and maintenance.

SECTION 6

EXAMINATION OF ENGINE DRIVERS, CRANE DRIVERS AND BOILER ATTENDANTS

During the year the Board of Examiners granted 157 Engine Drivers', 476 Crane Drivers' and 135 Boiler Attendants' Certificates of Competency.

Compared with 1967 these figures show increases of 40, 119 and 21, respectively. This is an overall increase of approximately 25% on figures for 1967.

The certificates granted do not tell the whole story as many applications are taken which, for one reason or another, do not reach that stage. During 1968, 919 applications were dealt with compared with 696 in the previous year. This is an increase approaching 50%. A considerable amount of time is expended by the Secretary to the Board of Examiners answering queries both at the counter and on the telephone.

In spite of the numbers of candidates examined the shortage of certificated operators continues especially in the crane field, where many cranes are driven by uncertificated drivers due, so we are told, to employers being unable to obtain men with certificates. This is a difficult field to police when the machines are working on projects many miles from Perth and staff is not available.

SECTION 7

STAFF AND GENERAL

The proposed transfer of this Branch from the Mines Department to the Department of Labour has still not been concluded but appears to be nearing finality. As a consequence of this the inspectorial staff position has remained almost static except for the creation of one new position Inspector of Machinery. This increase is grossly inadequate and coverage of our obligations under the Act has been correspondingly lacking. The two positions of temporary Supervising Inspector are still temporary. On the clerical side one extra assistant has been attached to the Branch pending the transfer.

One Inspector resigned during the year and returned to sea as he considered the remuneration inadequate. Filling of this vacancy has been delayed by an objection. Miss Vernon and Mrs. Mulcaster resigned from the Branch after a number of years of solid service. Mr. Angell was transferred to head office and one clerk and one assistant resigned.

An electronic calculating machine has been purchased for the Branch for use in design checking. Even in the short time we have had it it has proved a very worthwhile investment.

The work load has increased during the year in all areas but particularly in the North West and districts worked from Kalgoorlie. The necessity to station an Inspector in the North, as stated last year, is increasing and assistance is needed in Kalgoorlie. The expansion in the metropolitan and near city areas goes on unabated.

During the year a Committee, composed of representatives of the Statutory Authorities responsible for cranes, hoists and lifting gear, was formed. The object of this Committee is to procure uniformity of requirements in all States in the above mentioned areas. I have attended two meetings in this connection, both in Sydney. I feel that only good can come from these meetings for Statutory Authorities, Manufacturers and Owners.

Staff during the year have worked conscientiously, mostly under pressure, and indeed it has been necessary to institute overtime in some cases. Work has been done willingly and I am appreciative of the co-operative attitude displayed. Some temporary officers and relief staff have at times left something to be desired in their application to work.

The Police Department has again been of considerable assistance in the reporting of accidents and co-operation given where joint investigations have been made.

In conclusion, on behalf of all members of the Branch, I wish to record our appreciation of the assistance given by yourself and all Mines Department officers when requested.

E. J. McMANIS,
Deputy Chief Inspector of Machinery.

29th April 1969.

Return No. 1

SHOWING THE NUMBER OF BOILERS OF EACH TYPE AND COUNTRY OF ORIGIN OF NEW REGISTRATION FOR THE YEAR ENDED 31/12/68

Type of Boilers	W.A.	Eastern States (Total = 235)					England	Scotland	U.S.A.	Canada	Belgium	Sweden	Italy	Germany	Japan	Unknown	Total
		S.A.	Vic.	N.S.W.	Qld.	Tas.											
Air Receiver	137	3	48	35	....	....	17	3	14	....	7	2	2	....	....	18	286
Autoclave	2	....	3	3	....	....	....	....	....	....	....	....	....	1	....	....	9
Cornish	2	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	2
Digester	8	....	1	....	....	....	....	....	....	....	....	....	....	....	....	....	9
Gas Receiver	22	....	9	75	11	....	5	....	14	1	....	....	....	....	....	....	137
L.S.R.F.	1	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	1
Steam Jacketed Vessel	14	....	1	4	....	....	....	....	2	....	....	....	....	....	....	....	21
Steriliser	32	....	13	....	....	....	....	....	....	....	....	....	....	....	....	....	45
R.M.S.I.F.	125	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	125
Vert. Stat.	....	....	....	2	....	....	....	....	....	....	....	....	....	....	....	....	2
Vulcaniser	3	....	1	....	....	....	....	....	....	....	....	....	....	....	11	2	17
Water Tube	1	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	1
Not elsewhere specified	32	....	5	16	....	5	14	....	....	....	....	1	....	....	....	2	75
Total	379	3	81	135	11	5	36	3	30	1	7	3	2	1	11	22	730

TOTAL, 1967 = 634
TOTAL, 1968 = 730
INCREASE = 96

Return No. 2

SHOWING CLASSIFICATION OF VARIOUS TYPES OF USEFUL BOILERS IN PROCLAIMED DISTRICTS ON 31/12/68

Type of Boiler	Districts Worked from Perth	Districts Worked from Kal-goorlie	Total
Lancashire	29	27	56
Cornish	213	65	278
Semi-Cornish	14	1	15
Vert. Stationary	391	45	436
Vert. Port	30	12	42
Vert. Multi. Stat.	38	4	42
Vert. Multi. Port.	4	1	5
Vert. Pat. Tubular	49	....	49
Loco. Rect. F/box Stat.	72	17	89
Loco. Rect. F/box Port.	143	20	163
Loco. Circ. F/box Port.	84	3	87
Locomotive	74	12	86
Water Tube	538	57	595
Ret. Multi. U/fired Stat.	248	8	256
Ret. Multi. U/fired Port.	....	5	5
Ret. Multi. Int. Fired Stat.	428	17	445
Sterilisers	952	76	1,028
Autoclaves	125	3	128
Digesters	347	6	353
Gas Receivers	1,012	8	1,020
Air Receivers	3,102	864	3,966
Vulcanisers	458	11	469
Steam Jacketed Vessels	759	17	776
Not specified elsewhere	353	5	358
Total	9,463	1,284	10,747
Total out of use as at 31/12/68	2,253	858	3,111

Return No. 3

SHOWING OPERATIONS IN PROCLAIMED DISTRICTS DURING YEAR ENDED 31/12/68 (BOILERS ONLY)

Boilers	Districts Worked from Perth	Districts Worked from Kal-goorlie	1968	1967
Total number of useful boilers registered	9,463	1,285	10,748	10,099
New boilers registered during year	730	23	753	646
Boilers inspected thorough	5,756	327	6,083	5,475
Boilers inspected working	1,154	100	1,254	1,515
Boilers condemned during year temporarily	4	....	4	1
Boilers condemned during year permanently	61	3	64	109
Boilers sent to other States during year	93	....	93	134
Boilers sent from other States during year	235	....	235	162
Boilers sent from other countries during year	116	....	116	44
Boilers sent to other countries during year	3	....	3	7
Boilers transferred into district	8	45	53	....
Re-instated	1	....	1	2
Number of Notices of Repairs issued during year	713	80	793	718
Number of certificates issued, including those issued under Section 30 during year	5,756	373	6,129	5,821

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, 1968

	Districts Worked from Perth	Districts Worked from Kal-goorlie	Totals 1968	Totals 1967
Number of Groups driven by Steam Engines	119	366	485	485
Number of Groups driven by Oil Engines	4,320	946	5,266	5,008
Number of Groups driven by Other Power	174	202	376	344
Number of Groups driven by Electric Motor	50,803	4,181	54,984	50,732
Total	55,416	5,695	61,111	56,569

Return No. 5

SHOWING OPERATIONS IN PROCLAIMED DISTRICTS DURING YEAR ENDED 31st DECEMBER, 1968 (MACHINERY ONLY)

	Districts Worked from Perth	Districts Worked from Kal-goorlie	Totals 1968	Totals 1967
Total Registrations Useful Machinery	55,416	5,695	61,111	56,569
Total Inspections made	33,444	4,143	37,587	34,641
Certificates (Bearing Fees)	6,360	582	6,942	6,518
Notices issued (Machinery Dangerous)	654	185	839	659

Return No. 6

SHOWING CLASSIFICATION OF LIFTS AS AT 31st DECEMBER, 1968

Type	How Driven	Totals 1968	Totals 1967
Passenger	Electric	571	466
Passenger	Hydraulic	29	22
Goods	Electric	122	128
Goods	Hydraulic	9	11
Service	Electric	199	187
Service	Hydraulic	6	4
Escalators	Electric	54	49
		990	867

Increase in Registration—123.

(8)—62365

Return No. 7

FATAL AND SERIOUS ACCIDENTS FOR 1968

Classification of Industry	Milling	Buzzer	Circular Saw	Press	Lift	Plate Rolling and Rolls	Welding	Locomotive	Conveyor and Belts	Crane (Jib)	Superphosphate Spreader	Grinding	Crane (Overhead)	Printing	Band Saw	Spindle Moulder	Pumping	Lathe and Shaping	Guillotine	Pressure Vessel
Woodworking and Furniture	....	9	8	2	....	1	....	....	....	....	....	1	....	....	2	1	....	5	2	....
Metal Working and Engineering	1	....	2	6	....	1	1	....	....	1	2	7	3 1F	....	....	....	....	4	3	....
Food and Drink Processing	....	....	....	....	....	1	....	....	4	....	....	....	....	....	....	....	1	....	....	2
Printing and Allied Industries	....	....	....	....	....	1F	....	....	....	....	....	....	....	2	....	....	....	....	....	....
Mining	....	....	....	....	....	....	....	1	2	1 and 2F	....	....	....	....	....	....	....	....	....	....
Building and Allied Industries	....	....	2	....	....	....	....	....	3	3 and 1F	....	....	....	....	....	....	....	....	....	....
Wool Processing	....	....	....	....	....	....	....	....	2	....	....	....	....	....	....	....	....	....	....	....
Fertiliser Manufacture	....	....	....	....	....	....	....	....	1	....	....	....	1	....	....	....	....	....	....	....
Retail Store and Office Buildings....	....	....	....	....	3	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Waterfront	....	....	....	....	....	....	....	....	1F	1	....	....	....	....	....	....	....	....	....	....
Saw Milling	....	....	....	....	....	....	....	1	....	....	....	....	....	....	....	....	....	....	....	....
Stock Food	....	....	....	....	....	1	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Others	....	....	....	....	....	....	....	....	....	....	....	....	....	....	1	....	....	....	....	....
Totals, Type of Machine, 1968	1	9	12	8	3	4 and 1F	1	2	12 and 1F	6 and 3F	2	8	4 and 1F	2	3	1	1	9	5	2

Classification of Industry	Twisting	Cutting	Boring and Drilling	Punching	Fibre Teasing	Escalator	Chopping (wood)	Air Cramp	Cracker	Piemaking	Winch	Air Hose	Wool Preparation	Folding	Packing	Amusement	Extruding	Mincing	Winding Engine	Bending	Totals of Industries
Woodworking and Furniture	....	....	....	....	....	....	....	1	....	....	....	....	....	....	....	....	....	....	....	....	32
Metal Working and Engineering	1	2	3	1	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	1	39 and 1F
Food and Drink Processing	....	1	....	....	....	....	....	....	....	1	....	....	....	....	2	....	1	2	....	....	15
Printing and Allied Industries	....	....	....	....	....	....	....	....	....	....	....	....	....	1	....	....	....	....	....	....	3 and 1F
Mining	....	....	....	....	....	....	....	....	1	....	....	....	....	....	....	....	....	....	1F	....	5 and 3F
Building and Allied Industries	....	....	....	....	2	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	10 and 1F
Wool Processing	....	....	....	....	....	....	....	....	....	....	....	....	3	....	....	....	....	....	....	....	5
Fertiliser Manufacture	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	2
Retail Store and Office Buildings....	....	....	....	....	....	2	....	....	....	....	....	....	....	....	....	....	....	....	....	....	5
Waterfront	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	1 and 1F
Saw Milling	....	....	....	....	....	....	....	....	....	....	1	....	....	....	....	....	....	....	....	....	2
Stock Food	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	1
Others	....	....	....	....	....	....	1	....	....	....	....	1	....	....	....	2	....	....	....	....	5
Totals, Type of Machine, 1968	1	3	3	1	2	2	1	1	1	1	1	1	3	1	2	2	1	2	1F	1	125 and 7F

1967 = 94 and 4F

Return No. 7a

MINOR ACCIDENTS FOR 1968

Classification of Industry	Conveyors and Belts	Press	Crane	Buzzing and Abrasive	Hoist	Circular Saw	Can Washing	Lathe and Shaping	Escalators	Unloader	Lift	Printing	Mixing	Band Saw	Rolling	Cutting	Head Splitting	Freezing	Mincing	Filling	Spinning	Crane (Overhead Travelling)	Drilling	Skirting	Folding	Guillotine	Bending	Grooving	Totals of Industries
Woodworking and Furniture	1	....	....	5	1	3	....	....	....	1	....	1	....	2	....	....	....	....	....	....	....	....	....	....	1	....	....	1	16
Metal Working and Engineering	....	3	2	8	....	1	....	4	....	....	....	....	1	....	1	1	....	....	....	....	....	1	1	....	....	1	1	....	25
Printing and Allied Industries	1	....	....	....	....	1	....	....	....	....	....	2	....	....	....	....	....	....	....	....	....	....	....	1	....	....	....	....	5
Food and Drink Processing	2	....	....	....	....	....	1	....	....	....	....	....	....	....	....	....	1	1	1	1	....	....	....	....	....	....	....	....	7
Wool Industry	1	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	1	....	....	....	....	....	....	....	2
Retail Stores and Office Buildings	....	....	....	....	....	....	....	....	6	....	1	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	7
Building and Building Materials	2	1	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	3
Plastics Industry	....	....	....	....	....	....	....	1	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	1
Fertilizer	1	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	1
Totals, Type of Machinery	8	4	2	13	1	5	1	5	6	1	1	3	1	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	67

1967 = 50

Return No. 7b

ACCIDENTS CAUSED BY MACHINERY NOT COVERED BY ACT FOR 1968

Classification of Industry	Abrasive Wheels	Press	Elevator	Drill	Router	Jack Hammer	Crane (O.H.T.C.)	Sewing	Fork Lift	Escalator	Conveyor	Lathe	Circular Saw	Boring	Totals of Industries
Woodworking and Furniture	2	....	....	....	1	....	....	....	....	....	....	....	....	....	3
Metal Working and Engineering	4	....	....	1	....	....	1	....	....	....	1	1	....	1	9
Printing and Allied Industries	....	1	....	....	....	....	....	1	....	....	....	....	....	....	2
Food and Drink Processing	....	....	....	....	....	....	....	....	1	....	1	....	....	....	2
Stock Feed Manufacturing	....	....	1	....	....	....	....	....	....	....	....	....	....	....	1
Building Industries	....	....	....	....	....	1	....	....	....	....	....	....	1	....	2
Office Building and Retail Stores	....	....	....	....	....	....	....	....	....	1	....	....	....	....	1
Totals, Type of Machinery	6	1	1	1	1	1	1	1	1	1	2	1	1	1	20

(1967 = 21)

Return No. 8

SHOWING TOTAL OF ENGINE DRIVERS' AND BOILER ATTENDANTS' CERTIFICATES (ALL CLASSES) GRANTED IN 1968 COMPARED WITH 1967

—		Numbers Granted	
		1968	1967
Winding	Competency including Certificates issued under Reg. 40 and Section 60 of the Act	11	8
First Class	" " " " " Reg. 40 and 45 and Sections 60 and 63 of the Act	27	29
Second Class	" " " " " Reg. 40 and Section 60 of the Act	12	16
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	4	4
Traction	" " " " " Reg. 40 and Section 60 of the Act	....	....
Internal Combustion	" " " " " Reg. 40 and Section 60 of the Act	55	44
Crane and Hoist	" " " " " Reg. 40 and Section 60 of the Act	476	357
Boiler Attendant	" " " " " Reg. 50 and Section 60 of the Act	135	114
Diesel Loco.—			
Class A	" " " " " Reg. 40 and Sections 53 and 56 of the Act	33	24
Class B	" " " " " Reg. 40 and Sections 53 and 56 of the Act	1	1
Interim Certificates	.... Section 61	9	2
Copies	....	6	16
Applications Received : 1967 .... 696 Applications Received : 1968 .... 919 Increase in Applications = 46·8%.	Increase with 1967 .... 157 = 25·1%	783	626

Return No. 9

REVENUE AND EXPENDITURE FOR THE YEAR ENDED 31st DECEMBER, 1968, AND COMPARISON WITH PRECEDING YEAR

REVENUE

—	1968	1967
	$	$
Fees from Boiler Inspections	14,494.98	13,282.07
Fees from Machinery Inspections	23,575.00	20,111.68
Fees from Engine Drivers	3,023.00	2,414.20
Fees from Incidentals	678.53	499.35
Total	41,771.51	36,307.30

Increase in Revenue : $5,464.21.

EXPENDITURE

—	1968	1967
	$	$
Salaries	122,927.72	113,796.12
Incidentals	28,632.61	21,789.60
Engine Drivers' Examinations	520.44	841.71
Total	152,080.77	136,427.43

Increase in Expenditure : $15,653.34.

Return No. 10

SHOWING DISTANCES TRAVELLED, NUMBER OF INSPECTIONS MADE AND AVERAGE MILES TRAVELLED FOR INSPECTIONS FOR THE YEAR ENDED 31/12/68

——	Road Miles	Air Miles	Rail Miles	Water Miles	Collective Mileage all Transport Services	Number of Inspections	Average Miles per Inspection
Districts operated from Perth	151,228	5,890	*Nil*	*Nil*	157,118	40,355	3·89
Comparison with 1967	Inc. 12,384	Dec. 2,210	*Nil*	*Nil*	Inc. 10,174	Inc. 2,194	Inc. ·04
Districts operated from Boulder	13,404	*Nil*	*Nil*	*Nil*	13,404	4,570	2·93
Comparison with 1967	Dec. 3,170	*Nil*	*Nil*	*Nil*	Dec. 3,170	Inc. 1,000	Dec. ·87
Totals	164,632	5,890	*Nil*	*Nil*	170,522	44,925	3·79
Comparison with 1967	Inc. 9,214	Dec. 2,210	*Nil*	*Nil*	Inc. 7,004	Inc. 3,194	Dec. ·06

Note Abbreviations :—Inc. = Increase ; Dec. = Decrease.

Average Miles per inspection all districts, 1968 .... 3·79
Average Miles per inspection all districts, 1967 .... 3·85
Decrease per inspection compared with 1967 .... ·06

CONTENTS

DIVISION VII

Government Chemical Laboratories Annual Report—1968

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, 1968.

Administration:

The Laboratories consist of six 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.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., M.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—Vacant

Mineralogy, Mineral Technology and Geo-Chemistry Division—G. H. Payne, M.Sc., A.W.A.S.M., A.R.A.C.I., Divisional Chief.

Physics and Pyrometry Section— N. L. Marsh, B.Sc.

Librarian—Miss J. E. Maughan, B.A.

Office—Miss D. E. Henderson, Senior Clerk.

The close association of these Laboratories with other Government Departments, and with kindred associations was maintained during 1968 and various members of the staff are members of the following committees:—

Air Pollution Control 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.

Laboratory Safety 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.

Pesticides Residues Advisory 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.

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. During the year Dr. Uusna's three year term of office ended and his place was taken by a representative from South Australia.

The Pesticides Registration Committee dealt with 134 applications for registration of new pesticide formulations. The total number of applications considered by this Committee to 31st December, 1968 is 2164. 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 the active ingredient in the formulation to be distributed; or has restricted distribution to commercial pest exterminators. For the Swan River Conservation Board we analysed 150 samples of river water and 24 samples of effluents. The Veterinary Medicines Advisory Committee dealt with 1009 applications, being 767 renewals, 148 new registrations, 36 changes of formula or claim, 32 deferred, 21 not required to be registered and five rejected. During the year these Laboratories were registered as an approved research organisation by the Australian Industrial Research and Development Grants Board established under the Industrial Research and Development Grants Act, No. 51 of 1967 (Commonwealth).

It has not yet been possible to implement the re-organisation of the Agriculture and Water Supply Division referred to in my Annual Report for 1967 owing to the very slow progress in the re-classification of chemists in the Public Service but it is hoped that the re-organisation will be effected in 1969.

Staff

At 31st December, 1968 the staff of the Laboratories number 116, being—

Professional	66
General	34
Clerical	10
Wages	6

1968 proved a difficult year for staff, not, as in the past, the difficulty of obtaining sufficient suitable staff but in the number of changes of staff during the year. Staff changes, staff "turnover", in 1968 were more than twice those of any previous year. Hardly a week went by without resignation, calling applications, interviewing and selecting, and appointing. Apart from the time involved in such changes, they are unsettling and interrupt the free flow of work. Reduced output occurs also from the need to train new staff, even at the level of typists because of the not-usual nature of our language and reports.

A further disability, though not of staff, under which we laboured for much of the year, was the inconvenience and disruption inherent in the building of the multi-storey Mineral House in front of our office, between our Administration Block and Adelaide Tce. The attendant noise, dust and difficulty of entry inevitably reduced efficiency.

Obituary. It is with deep regret that I have to record the death on 22nd May, 1968 of the Chief of the Industrial Chemistry Division, Mr. Alexander Reid, M.A., B.Sc., A.R.I.C., A.P.I.A., M.S.P.I. The Industrial Chemistry Division was created in the 1946 re-organisation of these Laboratories and Mr Reid was the firt head of the new Division taking up duties on 3rd February, 1947. His was the difficult task of building from the beginning. It was a new venture for these Laboratories to enter the industrial world in this way and there were no precedents nor experience here to guide the new Chief. In addition, accommodation and equipment were minimal for the first few years and it was not till 1956 that a separate building fully equipped could be provided for the Industrial Chemistry Division.

Nevertheless Mr. Reid set to with a will and developed the Division to its present stage, the progress of the Division being shown in its Annual Reports since 1947.

Equipment

Major items of equipment obtained in 1968 included X-ray diffraction unit with Weissenberg goniometer, Grunier-Hagg focussing camera; Unicam SP200 G and SP 600 spectrophotometers; spectrofluorimeter; fluid bed heavy media separator; pneumatic pinched sluice.

Library

Additions to the Library in 1968 totalled 2873 items and included 181 books, 264 pamphlets, 1,600 periodicals (separate issues) 535 reports (separate issues). During the year 19 new periodicals were added making a total of 225 periodicals now taken by the Library. Loans to other Libraries were 164 and in turn we requested 468 loans from other Libraries. Items catalogued and indexed were 4,484.

Publications

During the year three Reports of Investigations were published and one paper submitted to the Journal of the Association of Official Analytical Chemists.

Table 1

SOURCE AND ALLOCATION OF SAMPLES RECEIVED DURING 1968

Source	Division							Total
	Agriculture and Water Supply	Engineering Chemistry	Food and Drug	Fuel Technology	Industrial Chemistry	Mineralogy	Physicist and Pyrometry Officer	
State—								
Agriculture Department	6,091	....	606	....	....	49	....	6,746
Agriculture College	20	....	....	....	....	....	....	20
Chief Secretary's Department	1	....	....	....	....	....	....	1
Crown Law Department	....	....	7	....	....	4	....	11
Education Department	6	....	....	....	....	....	....	6
Fire Brigade Board	....	....	1	....	....	....	....	1
Fisheries Department	129	....	11	....	....	....	....	140
Hospitals	2	....	61	....	....	....	....	63
Industrial Development Department	3	....	5	....	2	6	....	16
Infant Health	1	....	....	....	....	....	....	1
Labour Department	....	....	43	....	....	....	....	43
Lands & Surveys Department	....	....	....	....	....	....	1	1
Main Roads Department	....	....	2	....	8	28	....	38
Medical Department	34	....	....	....	....	1	....	35
Metropolitan Water Board	2,687	....	....	....	2	3	....	2,692
Milk Board	....	....	285	....	....	....	....	285
Mines Department	270	....	44	69	1	1,274	13	1,671
Museum	....	....	....	....	....	1	....	1
National Parks Board	8	....	....	....	....	....	....	8
National Coal Research Advisory Committee	....	....	....	1	....	....	....	1
Native Welfare Department	....	....	....	....	....	2	....	2
Perth City Council	....	....	....	....	....	1	....	1
Police Department	5	....	1,512	....	....	11	....	1,528
Public Health Department	69	....	357	....	....	6	....	432
Public Works Department	2,334	1	177	1	7	96	1	2,617
State Government Insurance Office	....	....	....	....	....	1	....	1
State Housing Commission	....	....	6	....	....	4	....	10
State Shipping Service	....	....	....	....	2	2	....	4
State X-ray Laboratories	....	....	....	....	....	....	1	1
Swan River Conservation Board	4	....	169	....	....	1	....	174
Titles Office	....	....	1	....	....	....	....	1
University of Western Australia	5	....	....	....	....	....	....	5
Western Australian Government Railways	....	....	4	....	....	....	....	4
Commonwealth—								
Air Department	2	....	....	....	....	....	....	2
Army Department	2	....	....	....	....	....	....	2
Bureau of Meteorology	....	....	....	....	....	1	....	1
Civil Aviation	1	....	....	....	....	2	....	3
Health Department	....	....	2	....	....	....	....	2
Navy Department	....	....	4	....	....	....	....	4
Postmaster General's Department	1	....	10	....	....	1	....	12
Royal Australian Air Force	13	....	....	....	....	....	....	13
Works Department	....	....	2	....	....	10	....	12
Public—								
Free	3	....	1	....	....	1,626	....	1,630
Pay	722	52	237	29	23	780	45	1,888
	12,413	53	3,547	100	45	3,910	61	20,129

General

The total number of registrations for 1968 was 5,022 an increase of more than 10 per cent. over the 4,419 registrations for 1967. The number of samples received in 1968 was 19,986 practically the same as in 1967 (20,570).

This was a welcome respite from the rapid increase in the previous few years and has enabled us to pause and consolidate. As a result the samples received but not reported at the 31st December, 1968 was 2,514 compared with 4,057 at 31st December, 1967. This is a very satisfactory result in view of the numerous staff changes during the year and has enabled us to give a more rapid and hence more satisfactory service to our many clients.

It has also enabled us to cope with the marked increase in samples of water for analysis consequent upon the introduction of fluoride into public water supplies early in January, 1968. Separate statistics of fluoridated water samples have not been kept but they are mainly responsible for an increase in water samples from 966 in 1967 to 2,678 in 1968 from the Metropolitan Water Board and from 646 in 1967 to 2,248 in 1968 from the Public Works Department; a total increase of 3,318 samples.

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 1968 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 cooperation 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, Commonwealth Government Departments, Hospitals, Milk Board, private firms and the general public, but the greater part of our work is done without charge for other State Government Departments, together with an appreciable amount of free mineral identification and assay to assist prospectors.

The summarised reports of the individual Divisions which follow show the very wide range of subjects dealt with by these Laboratories. Comparing 1968 with 1967 there were some marked alterations in the numbers of various types of samples received. These were:—

Marked increase	1967	1968
Animal specimens	23	381
Clover	1,074	1,645
Nickel	311	572
Titanium ores	49	109
Waters	3,265	5,969

Marked decrease	1967	1968
Apple leaves	356	60
Arsenic (geochemical)	572	—
Gold samples	885	448
Linseed	569	364
Lupins	208	36
Milk	699	367
Pasture	1,431	583
Silver ores	105	35
Soils	2,057	1,334
Tin ores	170	54
Wheat	2,031	195

The Deputy Director, Mr. R. C. Gorman, attended the Annual Conference of the Australasian Corrosion Association in Auckland, New Zealand, and was elected senior vice president of the Association.

L. W. SAMUEL,
Director.

AGRICULTURE AND WATER SUPPLY DIVISION

Samples into the Division increased from 11,534 in 1967 to 12,413, accounting for 62 per cent. of the total Laboratories receivals and continuing the trend shown graphically in last year's Annual Report, the proportions for the years 1965-68 being 42, 49, 56 and 62 per cent.

The output at 13,437 allowed us to substantially reduce the backlog of samples—to the extent that the work in hand at 1st January, 1969 now represents less than two months' output and we can supply most results within a time which is more satisfactory than for a number of years.

The staff in 1968 grew from 23 to a nominal 29, five people joining us during the year.

Equipment

The major items of equipment acquired were:—

(1) Spectrophotofluorimeter, C.G.A. 500R, primarily for the determination of selenium.

(2) Jar Test apparatus, for testing coagulation treatments of water.

(3) pH Meters, Radiometer 24 and 26, the former being portable for field determinations and the latter very sensitive when used as a potentiometer.

(4) Spectrophotometer, Unicam SP600 to supplement the larger SP500 unit.

Professional Associations

Mr. J. Jago spoke to the Analytical Group, Royal Australian Chemical Institute on "Spectrofluorimetry".

Mr. P. N. Jack spoke to the Hydrology Branch of the Institution of Engineers on "Water Treatment".

Mr. H. C. Hughes joined the committee of the West Australian Branch Royal Australian Chemical Institute, and Mr. N. Platell became President of the West Australian Branch of the Australasian Corrosion Association.

Soils

1. Of considerable present importance is the determination of the correct rotations of pasture and cropping which will give optimum return to farmers.

Multiple cropping offers short term financial returns but to the ultimate detriment of the soil.

Soils which had carried wheat crops each successive year for seven years, and which had received nitrogen fertilisers, either sulphate of ammonia,

Table 2

AGRICULTURE AND WATER SUPPLY DIVISION

	Agriculture Department	Agriculture College	Commonwealth Departments	Fisheries Department	Medical Department	Mines Department	Metropolitan Water Board	Public Free	Public Health Department	Public Pay	Public Works Department	Royal Australian Air Force	Other Government Departments	Other	Total
Animal—															
Blood	62	....	....	....	....	....	....	....	....	....	....	....	....	....	62
Kidney	12	....	....	....	....	....	....	....	....	....	....	....	....	....	12
Liver	77	....	....	....	....	....	....	....	....	....	....	....	....	....	77
Sheep tissue	144	....	....	....	....	....	....	....	....	....	....	....	....	....	144
Wool	60	....	....	....	....	....	....	....	....	....	....	....	....	....	60
Various	15	....	....	....	....	....	....	....	10	....	1	....	....	....	26
Cereals—															
Barley grain	24	....	....	....	....	....	....	....	....	....	....	....	....	....	24
Wheat grain	85	....	....	....	....	....	....	....	....	3	....	....	....	....	88
Plants	107	....	....	....	....	....	....	....	....	....	....	....	....	....	107
Various	41	....	....	....	....	....	....	....	....	....	....	....	....	....	41
Fertilizer—															
Fertilizer	9	....	....	....	....	....	....	....	....	11	....	....	....	....	20
Fertilizer Act	97	....	....	....	....	....	....	....	....	....	....	....	....	....	97
Lime	1	....	....	....	....	....	....	....	....	17	....	....	1	....	19
Seaweed	14	....	....	....	....	....	....	....	....	....	....	....	....	....	14
Various	4	....	....	....	....	....	....	....	....	6	....	....	....	....	10
Horticulture—															
Apple leaves	60	....	....	....	....	....	....	....	....	....	....	....	....	....	60
Banana leaves	11	....	....	....	....	....	....	....	....	....	....	....	....	....	11
Citrus leaves	43	....	....	....	....	....	....	....	....	....	....	....	....	....	43
Currants	17	....	....	....	....	....	....	....	....	....	....	....	....	....	17
Orange leaves	72	....	....	....	....	....	....	....	....	....	....	....	....	....	72
Various	41	....	....	....	....	12	....	....	5	....	....	....	....	....	58
Miscellaneous—															
Abalone	....	....	....	21	....	....	....	....	....	....	....	....	....	....	21
Corrosion	....	....	....	....	9	7	....	1	....	14	14	....	....	....	45
Effluent	....	....	....	2	....	10	....	....	3	....	34	....	4	....	53
Various	....	....	....	7	....	2	9	....	2	20	37	....	5	1	83
Pasture and Fodder—															
Cape weed	20	....	....	....	....	....	....	....	....	....	....	....	....	....	20
Clover	1,645	....	....	....	....	....	....	....	....	....	....	....	....	....	1,645
Clover and lupins	365	....	....	....	....	....	....	....	....	....	....	....	....	....	365
Feeding Stuffs Act	71	....	....	....	....	....	....	....	....	1	....	....	....	....	72
Feeding Stuffs	8	....	....	....	....	....	....	....	....	3	....	....	....	....	11
Grass	126	....	....	....	....	....	....	....	....	....	....	....	....	....	126
Grass and weeds	273	....	....	....	....	....	....	....	....	....	....	....	....	....	273
Hay	2	....	....	....	....	....	....	....	....	11	....	....	6	....	19
Kikuyu	156	....	....	....	....	....	....	....	....	....	....	....	....	....	156
Legumes	463	....	....	....	....	....	....	....	....	....	....	....	....	....	463
Lucerne	35	....	....	....	....	....	....	....	....	....	....	....	....	....	35
Lupin	36	....	....	....	....	....	....	....	....	....	....	....	....	....	36
Pasture	581	....	....	....	....	....	....	....	....	2	....	....	....	....	583
Various	33	....	....	....	....	....	....	....	....	13	....	....	....	1	47
Soil	1,267	20	....	....	....	17	....	....	8	22	....	....	....	....	1,334
Water	14	....	6	99	25	222	2,678	2	41	599	2,248	13	11	6	5,964
	6,091	20	6	129	34	270	2,687	3	69	722	2,334	13	27	8	12,413

urea or calcium-ammonium-nitrate, were analysed for their cation content and pH. At two of the three sites the plots which had received high rates of sulphate of ammonia had for several years given significantly lower yields.

At these two sites at Wongan Hills and Merredin, sulphate of ammonia used at 336 lb. per acre over seven years had affected the top four inches of soil as shown below. At Avondale with a soil of twice the exchange capacity the effects were taking longer to develop.

Sulphate of ammonia with the double acidifying effect due to the oxidation of the ammonia to nitrate and the release of sulphate anions is lowering the pH, increasing the exchangeable hydrogen at the expense of exchangeable bases.

To a lesser extent the same acidifying effect was progressing with the other sources of nitrogen on the more sandy Wongan and Merredin soils but was not detectable at Avondale.

2. To provide additional information on the irrigation potential of soils from the Pilbara, mechanical analyses and exchangeable cations were determined on samples from Mardie and Warambie Stations. Those which had been found suitable physically were believed to have excessive salt levels for irrigation.

The surface at each site had a pH of at least 8, and in several cases in excess of 9. Samples contained as much as 18 per cent. of acid soluble material, primarily lime and gypsum.

3. Soils from the Murchison on Belele Station were from areas carrying saltbush and grazed or enclosed, or another where an attempt to regenerate mulga was being made. Samples were primarily only the top ¼ inch, and none deeper than 2 inches but in only one instance did the nitrogen content reach 0.1 per cent. and the carbon 1 per cent., reflecting the sparseness of the vegetation.

In some cases where the soil was more sandy, nitrogen was only 0.02 per cent. and carbon 0.2 per cent. but some improvement was evident when the ground had been protected from grazing stock.

4. The bulk of the soil samples received were concerned with the maintenance of phosphorus and sulphur levels by use of fertilisers at varying rates under varying cropping or stocking regimes. These have been fully reported at earlier stages. Many more samples involved work with nitrogen, either

	Wongan Hills		Merredin		Avondale	
Treatment sulphate of ammonia, per acre	nil	7 × 336 lb.	nil	7 × 336 lb.	nil	7 × 336 lb.
pH	6·0	5·0	6·0	4·7	6·0	5·2
Cation Exchange Capacity (milliequivalents per 100g)	3·2	3·0	3·0	3·1	7·8	6·0
Total Exchangeable Bases (milliequivalents per 100g)	2·5	1·5	2·0	1·4	6·5	3·8
Base Saturation (percentage)	77	51	68	43	82	63

by fertiliser application or growing of leguminous pasture and, interim results having appeared in the last two Annual Reports, further reports will await more significant developments.

5. Private sources provided soils for salinity and pH testing where, as in areas subject to a rising water table or in specific instances such as bowling greens, these could be factors in obtaining any plant growth or maximum cover.

It was found for instance at Chidlow that the hybrid pasture plant Sudax was giving only poor growth on soil with 0.4 per cent. total soluble salts and good growth where salinity was less than 0.2 per cent.

Fertilisers

1. Fertilisers Act.—Analyses were completed on 81 of 97 samples received under the Act. A feature again was the number of samples in which the claimed content of trace element was found not to be present, even allowing for the 10 per cent. by which this may fall short.

Molybdenum in superphosphate was found to be deficient in 15 of 17 samples in which it was registered. This was too high a proportion to be explained by the difficulty of mixing a small amount into a large bulk.

Mixing difficulty might better explain the 5 of 15 samples deficient in copper and 4 of 13 deficient in zinc.

2. Compound Fertilisers.—These are now receiving much publicity and being used in experiments to determine their effectiveness in comparison with longer established sources of nitrogen and phosphorus and also to assess the effect of their low sulphur content.

Analyses of two samples were:

	N:P Compound 24:24	N:P Compound 28:14
	per cent.	
Moisture	5.03	3.10
Nitrogen,N	23.3	27.4
Sulphur,S	0.36	0.24
Phosphorus,P—		
water soluble	9.60	5.43
citrate soluble	0.48	0.22
acid soluble	0.03	0.01
total	10.1	5.66

The total phosphorus in these two samples when expressed as "P_2O_5, phosphoric anhydride" is equivalent to 23.1 per cent. and and 13.0 per cent. respectively.

3. Nitrogen Enriched Coal.—A sample of coal impregnated with ammonia and planned to be used as a slow release fertiliser contained 14.1 per cent. of total nitrogen, less than 0.05 per cent. of nitrogen in a water soluble form and 2.6 per cent. so called "available nitrogen" determined by reaction with alkaline permanganate.

An additional assessment of availability was obtained by a comparison of the rate of release of the nitrogen from the coal with the release from a sample of blood and bone (5.5 per cent. total N), by incubating the fertilisers with soil. The soil used was that on which a field trial was in progress.

After 10 days' incubation the amount of nitrogen released from the coal was 0.3 per cent. (2.2 per cent. of the total nitrogen) compared with 1.3 per cent. (23 per cent. of the total nitrogen) from the blood and bone.

From the field trial we obtained 156 samples of kikuyu grass representing six fortnightly cuts from an experiment comparing nitrogen enriched coal with other nitrogenous fertilisers. The fertiliser had been applied at rates equivalent to 45, 90 and 180 lb. per acre of nitrogen, N, in a single application or in three smaller dressings.

Nitrogen enriched coal, even at the highest application rate, did not increase the nitrogen content of the grass except possibly at the first cut, nor did it produce more dry matter than the control (nil) treatment. Blood and bone, at each application rate, increased the nitrogen content of the grass but dry matter production was increased only by the highest rate.

The effect on nitrogen content of the single dressing of all fertilisers disappeared by the time of the fourth cut. Urea and sulphate of ammonia gave clear increases in production, 40 per cent, and marked increase in nitrogen content of the herbage.

The experiments confirmed results obtained elsewhere with nitrogen enriched coal and indicated that prospects for its use as a fertiliser in Western Australia are not encouraging.

4. Rock phosphate and sulphur granules made in these Laboratories and of which the composition was given in the 1967 Annual Report, were used on a property at South Stirlings as a fertiliser for oats and clover on new land having a soil with a low phosphorus saturation value.

The granules, whether of rock phosphate alone or with sulphur addition, were inferior to superphosphate as has been shown for rock phosphate alone previously.

The incorporation of sulphur in the granules did not enhance the availablity of the phosphorus.

5. Seaweeds of a number of species found along the coast near Perth were tested for their nutrient and salt contents to gain a better idea of their value if used as fertiliser.

A rinse with fresh water was considered probably advisable to reduce the salt content but this did not affect the salt content of the dried material as greatly as the nature of the seaweeds, some of which held the salt within their cell structure. The range of composition from 13 varieties was:

	dry basis per cent.
Chloride, Cl	1.20—26.4
Nitrogen, N	0.54— 2.6
Phosphorus, P	0.02— 0.25
Potassium, K	0.48— 9.03
Calcium, Ca	0.40— 5.5
Magnesium, Mg	0.30— 3.1
	ppm
Boron, B	110—2000
Copper, Cu	1.8— 92
Manganese, Mn	2.1— 137
Molybdenum, Mo	0.03— 1.0
Zinc, Zn	7.9— 121

The low nitrogen content indicates that unless more is added to aid decomposition, an induced nitrogen deficiency may result as with other plant material.

Some seeweeds also will be harmful to salt susceptible plants if applied direct.

Clearly seaweed is best treated as a material for composting.

6 A sample of fertiliser produced from municipal waste by a patented process proved to have similar composition to vegetable compost except that, having a high carbon : nitrogen ratio, it would require the addition of further nitrogen or it would tend to deplete a soil to which it was added of this element during further decomposition.

7. The majority of fertilisers, or proposed fertilisers, from private sources were limesands, 23, and lake deposits, 7, believed to be primarily gypsum.

Others were from farmers checking that the composition of fertiliser delivered to them was as ordered, including such things as magnesium sulphate and calcium nitrate, but most often superphosphate with trace element additions.

Pastures, Fodders and Stock Foods

1. Feeding Stuffs Act. The need for review of the Feeding Stuffs Act, as of the Fertilisers Act, was emphasised by the 71 samples received this year. An effort had been made to cover many more of the less commonly used feeding stuffs intended for particular types and ages of stock. Among them, deficiencies and excesses were frequent, the Act allowing no margin, but the practice of including in the preparation of some feeding stuffs some proprietary lines which are registered as veterinary medicines lead to some confusion over the application and administration of these Acts.

Confusion may also arise, particularly and understandably for the lay people to whom the Act applies, and among the inspectors charged with its supervision, because of the outmoded practice of registering calcium content as "lime CaO" and phosphorus as "phosphoric acid P_2O_5" when the food contains neither lime nor acid.

2. Clovers and clover pastures.

(a) Trace Elements: (i) Much work continues with testing of residual value, from copper fertilisers of various kinds on differing soils, of copper in clover pastures.

On a gravelly loamy sand at Woogenellup which is acutely copper deficient, Dinninup sub-clover had been variously treated in 1961 with copper sulphate, oxide, sulphide or carbonate ores of differing degrees of fineness and/or roasting, and at rates equivalent to 3 and 9 lb. per acre of copper sulphate.

Samples cut in October, 1966 contained, as the mean of 4 replicates, 3.5 ppm dry basis copper, Cu when no copper had been added, 4.0 and 4.4 ppm from the copper sulphate treatments and in the main as high or higher levels from the ores. However these levels are currently considered to be at best low-normal when the clover is assessed for its feed value.

The 1967 cut of this trial indicated rather better residual effects from the oxide than the sulphate, but the big differences between replicates indicated the possiblity of significant transport between plots over the seven seasons of the experiment.

A similar experiment at Narrogin showed a fairly regular increase in copper uptake in 1966, with addition of up to 24 lb. per acre of copper sulphate equivalent two years previously, the range being from 1.8 ppm without treatment to 5 ppm at the 16 lb. per acre level. The following year all but the 16 and 24 lb. per acre were showing appreciably lower copper contents. The copper oxide remained equal to the sulphate but the 8 lb. equivalent of South Australian super-copper was only as good as the 4 lb. rate of the other treatments.

(ii) In an endeavour to determine the rates of copper and cobalt sulphates necessary to maintain adequate levels for animal health, combined rates of copper sulphate from 1 to 8 lb. per acre and cobalt sulphate from 2 to 16 oz. per acre were applied to a clover pasture on Fleming sand on a property at Munglirup in the Esperance district.

For the soil having been top dressed three years previously with a copper-zinc fertiliser little additional benefit was shown in copper levels, already 9 ppm, but cobalt, only 0.06 ppm. dry basis without treatment went to more than 0.2 ppm with the minimum treatment and up to 0.7 ppm at the maximum rate.

With similar treatments were samples from two experiments in the Mount Barker district, one on gravel and the other on sand. The fertilisers had been applied in the year of sampling and cuts made in late winter and late spring.

The gravel soil was perhaps not a well chosen site in that even without treatment both cobalt and copper were at nutritionally adequate levels for stock at both times of cutting. This was confirmed when the samples from the nil plots gave in excess of one part per million of cobalt.

Of more significance were experiments in the Bridgetown district where no improvement was obtained on new land with deep sand for either nutrient at even the highest levels. On a gravelly soil however where copper levels were adequate without treatment there was an improvement in cobalt from the deficiency content of 0.05 ppm before treatment to a probably sufficient 0.08 ppm with 4 oz. per acre cobalt sulphate, and higher concentrations with heavier rates of application.

Ready improvement in cobalt was obtained on another site at Lancelin where only 2 oz. per acre of cobalt sulphate improved cobalt concentration from less than 0.1 ppm to about 0.25 ppm and with further increases up to 1.2 ppm for the 16 oz. per acre rate. It had been anticipated that some improvement in nitrogen status might show for this acutely cobalt deficient area but none was obtained.

That any benefits from cobalt are unlikely to be as long lasting as those obtained from copper was illustrated at Forrest Hill where in the third year after application the only residual benefit was from 12 oz. per acre or more.

(b) Sulphur. (i) Two glasshouse trials were commenced to investigate the comparative nutrition of some sub-clover cultivars. There were 12 varieties each receiving 5 levels of sulphur in the soil, from nil to 32 ppm. Samples were taken at four stages of growth and the various parts of the plants were analysed for sulphur and nitrogen forms, involving some 2,400 analyses. The results obtained have yet to be fully assessed but Table 3 gives an indication of the range of values. The figures are the mean of four replications of the leaves from the second sampling in July, for total sulphur, S and total nitrogen, N.

Table 3

Clover variety	Geraldton		Woogenellup		Rose		Yarloop	
Treatment Sulpnur	S	N	S	N	S	N	S	N
	%	%	%	%	%	%	%	%
nil	0·16	5·44	0·15	5·50	0·18	4·75	0·15	5·44
4 p.p.m.	0·26	5·42	0·14	5·93	0·20	5·02	0·18	4·94
8 p.p.m.	0·26	5·16	0·22	5·58	0·24	4·64	0·20	4·36
16 p.p.m.	0·31	5·16	0·24	5·63	0·25	4·48	0·26	4·55
32 p.p.m.	0·45	5·32	0·30	5·80	0·44	4·51	0·30	5·21

(ii) A number of experiments were commenced in 1967 to investigate the response by sub-clover pastures to sulphur with and without adequate phosphorus. Table 4 shows the concentrations of total sulphur and nitrogen obtained from one of these experiments at the Chapman Research Station. The figures are the mean of two replications and five rates of gypsum treatment. The presence or absence of added phosphate fertiliser caused little difference to the sulphur or nitrogen content and there was little variation in the range of values obtained with from nil to 30 lb. per acre of gypsum.

Table 4

Phosphorus Treatment	Clover				Grass				Weeds			
	Nov. 67		Apr. 68		Nov. 67		Apr. 68		Nov. 67		Apr. 68	
	S	N	S	N	S	N	S	N	S	N	S	N
	%	%	%	%	%	%	%	%	%	%	%	%
with	0·17	2·73	0·15	2·38	0·16	1·95	0·09	1·09	0·20	2·58	0·11	1·50
without	0·22	2·76	0·15	2·57	0·20	1·68	0·09	1·00	0·18	2·01	0·12	1·32

(c) Phosphorus. On a phosphorus and lime trial on a Jarrah gravel soil at Bridgetown—a soil with a high phosphate fixing capacity—there had been slight benefits from lime rates in the absence of superphosphate, largely visible in the non-clover fraction but also giving healthier clover at moderate lime levels. At high lime levels yellowing had been evident.

Cuts of the clover made in July showed no significant differences in nitrogen, phosphorus, copper or zinc concentrations in the absence of superphosphate and although manganese was down from of the order of 50 ppm, at even the 80 cwt. per acre treatment level, the content was still 40 ppm in the dry matter.

Superphosphate treatments raised the phosphorus concentration from approximately 0.27 per cent. to 0.40 per cent. when 180 lb. per acre was used, irrespective of lime.

The November cut, with lower all-over nutrient levels, gave the same story as the July cut for N, P, Cu and Zn, and the manganese showed even less indication of suppression by lime.

In July the grass and other components of the pasture showed a fall in nitrogen content when the lime addition reached one ton per acre in the absence of superphosphate but the variability found in the results with the two rates of superphosphate at each lime rate suggested that this was probably fortuitous. Except at the highest rate of 180 lb. per acre of superphosphate there was some evidence that phosphorus with or without superphosphate was made more available to the grass by the lime. Copper was somewhat suppressed by lime from 14 ppm without lime to 12 ppm at the 4 ton per acre rate and zinc also was affected from 40 to 36 ppm but the greatest effect was on manganese levels, these being reduced from 75 ppm to 45 ppm.

The November grass component showed no effect of lime on N, P, Cu or Zn but the high rates of lime lowered the manganese and at each rate of lime increasing superphosphate treatment emphasised this effect, manganese being down to 15 ppm and less at maximum rates.

There was some question that aluminium toxicity could be a factor in this experiment but the difficulty of sampling in the field to avoid soil contamination obviated any deductions from analytical results on this point.

Although the reduction in manganese to deficiency levels was shown in the end of season samples there was no other evidence to account for the visible effects of the lime treatments, but often if the treatment results in improved nitrogen metabolism the increased growth will result in lower nitrogen concentrations and not an increase.

Miscellaneous Pastures and Feeding Stuffs.

1. Selenium.—The first diagnosed case of White Muscle Disease at Dandaragan was found on a property where the pasture contained only 0.02 ppm of selenium in the dry matter. Outbreaks at Badgingarra and further inland at Piawaning were on properties where the feed, whether pasture or oaten hay, did not exceed 0.03 ppm.

2. Cobalt.—Abnormally high cobalt figures were obtained from pasture at Esperance. A trial of sheep responses to cobalt and selenium was being carried out. Within one paddock 6 samples were taken, one in each corner and two centrally. Cobalt contents ranged from 0.35 to 1.5 ppm dry basis. No cobalt had ever been used in fertilising the pasture which was dressed with superphosphate after being sown together with a cover crop of barley and oats using super-copper-zinc fertiliser. The selenium ranged from 0.02 to 0.06 ppm.

Many reports of illthrift from the Badgingarra-Dandaragan area came from properties where none of the pasture analyses exceeded 0.05 ppm of cobalt.

On the other hand illthrift at Esperance could not be attributed to the cobalt content which ranged from 0.4 to 0.8 ppm of the dry matter, figures of the same order as found on the experimental site above.

3. When cut in July phosphorus levels were increased from 0.14 per cent. to 0.26 per cent. in pasture grown at Bramley by the use of superphosphate up to 300 lb. per acre. In these same samples sulphur concentration was initially suppressed.

Treatment Superhosphate lb. per acre	Sulphur,S dry basis per cent.	Phosphorus,P dry basis per cent.
0	0.16	0.14
50	0.12	0.15
100	0.10	0.14
200	0.13	0.20
300	0.14	0.21
400	0.16	0.26

A limited comparison was made at the same time using the rock phosphate-sulphur granules mentioned under Fertilisers.

The concentration obtained when the granules were used at rates equivalent to the phosphorus content of the superphosphate were—

Treatment lb. per acre	Sulphur,S dry basis per cent.	Phosphorus,P dry basis per cent.
100	0.13	0.15
200	0.17	0.18
300	0.17	0.16

This again illustrated failure to release phosphorus to the plant.

4. Native species.—Danthonia bipartita and Neurachne mitchelliana growing at Barnong Station were sampled throughout the season to assess the rise and fall of protein and fibre contents and find the power of recovery of the plants. Fertiliser was applied to Danthonia in some plots in an endeavour to improve productivity both in quality and quantity.

Protein contents improved by the use of urea in 3 separate dressings to be about 10-12 per cent. on a dry basis in September, but even 300 lb. per acre of superphosphate made no difference to phosphorus content.

5. Wild turnip seed is a contaminant of some wheat crops and has to be removed for sale of the grain. Because of its high protein content it has some value as feed stuff.

	Wild Turnip Seed per cent.
Moisture	8.7
Ash	3.60
Crude protein (nitrogen x 6.25)	26.6
Crude fat (petroleum ether extract)	24.5
Crude fibre	10.3
Nitrogen free extractives	26.3
Calcium,Ca	0.45
Phosphorus,P	0.55

The fat, or oil, and with it a toxic principle, is best extracted to give a protein rich meal.

6. Leaf material from Weiko lupins growing commercially at Wanneroo had symptoms of manganese deficiency. A comparison of healthy and unhealthy samples showed less than 20 ppm of Mn in the latter. This level, and those of healthy material which were as high as 90 ppm, was well removed from the manganese found in blue lupin leaves from the Moora region which averaged 370 ppm on a dry basis.

A survey of other Weiko lupin seeds from crops grown from the north at Badgingarra, central coastal districts and the south-west contained from 5 to 50 ppm tending to be higher from more southerly and inland areas. Blue lupin seed contained from 21 to 345 ppm manganese, averaging 64 ppm.

7. Molasses was examined for its feeding stuff value which lies almost entirely in its carbohydrate content—in this case sugars—approximating to the nitrogen free extractive.

	Molasses
	per cent.
Moisture	17.4
Ash	7.9
Crude protein	3.9
Crude fat	0.1
Crude fibre	less than 0.1
Nitrogen free extractive	70.7
Calcium,Ca	1.07
Phosphorus,P	0.09
Sodium chloride,NaCl (calc. from chloride)	2.08

8. A local resident was contemplating the use of dried shark flesh for feeding to pigs or cattle at Roebourne. The urea content of shark flesh is available to ruminants.

	Dried Shark
	per cent.
Moisture	9.6
Crude protein (nitrogen x 6.25)	98.1
Crude fat	0.8
Calcium,Ca	1.08
Phosphorus,P	1.48
Urea $(NH_2)_2CO$	6.4
equivalent to protein	18.8
Crude protein proper	79.3

Cereals

1. Barley.—As a further factor in the decision made by the Coarse Grains Advisory Committee for the release of the new variety Bussell the fibre content of grain samples grown at widespread sites was compared with the fibre content of the established Beecher barley. In every instance Bussell contained approximately one per cent. less fibre than Beecher and thus more of the desirable constituents of the grain.

2. Wheat.—(a) The protein content of the 1967-1968 season F.A.Q. wheat was improved at 10.1 per cent. on a 13.5 per cent. moisture basis by comparison with 9.3 per cent. from the previous year. The range of zone samples this season was from 9.4 per cent. at Albany to 10.1 per cent. at both Esperance and Fremantle. Flours from the grains contained maltose ranging from Esperance, the highest, at 281 mg. per 10 g. to that at Albany 226 mg. per 10 g.

(b) Wheat crops from the Salmon Gums district were tested for zinc, sulphate and manganese. There had been indications of zinc deficiency on these heavier soils and if confirmed would be the first occurrence on such soil. The levels found confirmed the diagnosis when samples from first crops on virgin areas contained 13 to 14 ppm dry basis, when treated with compound fertiliser as little as 11 ppm, and even areas with a long history of cultivation gave plants containing up to 18 ppm which is on the border of deficiency and sufficiency.

(c) The copper and zinc status of wheat grown at the Kimberley Research Station proved satisfactory when it was found that wheat leaves which had received heavy applications of N : P fertiliser contained on a dry basis 11 to 12 ppm copper and 24 to 26 ppm zinc. Other nutrients determined for additional information were nitrogen, phosphorus and potassium, respectively averaging 4.4, 0.28 and 2.9 per cent. dry basis, and manganese 33 ppm on dry basis.

(d) A large amount of work on wheat was in determining the nitrogen status of the plant in relation to the fate of nitrogen fertilisers or the response of various varieties in different wheat growing areas.

Results on grain samples were reported in 1967 and the plant levels of nitrogen tell a similar story in that in each area in which it was grown, i.e. all except Merredin, Festiguay was the leading variety for protein content.

Horticulture

1. Apples.—In an endeavour to identify deficient elements and also provide evidence of deficient levels for apple trees in the Donnybrook area leaves from unthrifty trees, average and healthy trees were taken from both light and heavy soils. The outstanding features of the results were the low phosphorus levels found in poor trees. 0.07 to 0.12 per cent. dry basis, and that some trees said to be either average or healthy nevertheless contained as little as between 1 and 2 ppm of copper.

As a first aproximation from these 14 samples the critical level might be nitrogen 2.0 per cent., phosphorus 0.16, potassium 1.4 per cent. for the major elements wherein there was some correlation between nutrient level and condition of the trees. These compare with the levels suggested by Emmert, N.Z. J. Agric. Res. 1962, 5, 381 of 1.9-2.4. 0.18-0.26, 1.2-1.8 respectively.

The difficulty of this type of work with apples was emphasised when further sampling at Donnybrook in the next year for the same purpose complicated the picture when half of the samples from unthrifty trees exceeded 2.0 per cent. nitrogen; no sample whether healthy or poor contained in excess of 0.16 per cent. phosphorus, and only 2 of 10 poor trees gave less than 1.4 per cent. of potassium.

2. Citrus.—(a) A survey similar to that on apples leaves at Donnybrook was carried out in areas near Bunbury where oranges, primarily Valencias, are grown under irrigation. In the case of citrus the nutrient correlation levels established in the U.S.A. and N.S.W. have in the past been found to be applicable in W.A.

In this instance high levels of chloride—approximately 0.23 per cent.—were found in some leaves but generally levels of all nutrient were satisfactory.

The exception was molybdenum in young trees where levels were only 0.02 to 0.03 ppm on dry basis, but the same for both healthy and distorted leaves.

(b) The grey sandy soil of Maida Vale was expected to provide low levels of trace elements not otherwise supplied, except through sprays containing copper.

Manganese and molybdenum were confirmed as probably deficient but results were at satisfactory levels for iron and zinc. Magnesium was found to be deficient in orange but not lemon leaves on this same property.

On an adjacent property soil application of trace element fertiliser raised foliar levels of copper, manganese and zinc and leaf spray had the same result on oranges.

3. Grapes.—No nutritional work was performed this year but moisture studies were made on dried currants for two reasons:

Firstly the ability of the fruit to withstand the beating of the cleaning process is related to moisture content and temperature control in the cleaning shed.

Secondly to discover the variations in moisture of the fruit stored in cardboard cartons lined with waxed paper on the sides but not the ends, and stacked in open sheds. 28 lb. of fruit were reported to increase in weight by up to 1 lb.

Exposure on sheets of plastic in the field resulted in lower moisture content than normal racking, but whether so exposed or not the surface fruit in boxes removed to racks in the shed took up of the order of 1.5 per cent. of moisture from the humid atmosphere.

After packing and storage those cartons which were on the outside of the stack had a variation in moisture content between fruit in the centre of the carton, averaging about 14.3 per cent., and fruit against the walls of the carton at about 18.2 per cent. Cartons in the centre of the stack did not have any moisture variation.

4. Carnarvon Irrigation.—Problems have occurred in bananas, beans and other fruit and vegetables grown under irrigation both on the Gascoyne Research Station and among commercial crops, which have resulted in extensive chemical work on plant parts, waters and soils to find whether there are individual nutritional or pathological problems or whether all are related to water quality, cultivation and pest control practices and soil properties.

Water Treatment and Supply

1. Corrosion, Scales and Deposits.—(a) The staining of the beach along the coast from the outfall of the Laporte effluent has been a cause for concern. The effluent contains iron and some titanium in solution in dilute sulphuric acid, and a suspension of undissolved mineral matter. The lime content of the sand forming the pond or lagoon into which the effluent is discharged before reaching the sea provides some neutralisation and settling of the suspended solids. Tests confirmed that in the absence of aeration, neutralisation does not cause precipitation of more than one-fifth of the iron as "rust"—iron oxide.

Seawater however provides rapid neutralisation and aeration of that portion of the discharge which reaches it. Samples of sand and rock from the seabed showed that most of the iron oxide was in a non-dispersible form. This means that the deposit will not readily wash off, and transport of the sand particles themselves would be necessary to remove the discolouration.

Bore hole samples taken below the water table between the lagoon and the shoreline and 20 ft. beyond the shoreline to 6 ft. depth, showed that some of the effluent was to be found to this depth, the acidity and proportion of iron in solution increasing with depth below the seabed.

(b) Corrosion of water meters in the town supplies of Capel, Eaton, Exmouth and Northampton was found to have the following in common:—

(i) The water supplies are or have been chemically treated to make the water near saturated or supersaturated with respect to lime or else this condition is natural to the water.

(ii) The attack on bronze plates is as severe or more severe than attack on the brass cylinders although the composition of the former should render them more resistant to the common forms of corrosion.

(iii) The attack on the metal seems to have been dezincification at first, followed by corrosion of the residual copper.

(c) The use of α-brass or bronze screws was advised in place of brass screws containing less than 70 per cent. copper which had been used in the cooling system of the Superannuation Building. The screws high in zinc content had corroded by dezincification and possible contamination of the recirculating water by exhaust gases from the oil fired heaters was eliminated as a cause.

(d) Surface attack on some of the aluminium cover plates and uprights of the balustrading of the Malcolm Street bridge over the Mitchell Freeway was initially believed to be caused by some alkaline material probably from cleaning compounds used in removing bitumen from the concrete.

A further inspection during construction of the Hay Street bridge showed that filling of the uprights by rainwater could occur before capping. This water had dissolved some of the components of the cement grouting at the base making the water alkaline and hence corrosive to aluminium.

Recommendations were made to drain the uprights and ensure that the capping piece to the rail was placed in position before rain.

(e) The condenser water system of the new Government offices in West Perth was inspected with officers of the Public Works Department because of corrosion problems. The current water treatment had provided negligible inhibitive effect because the recommended inhibition dosage had not been maintained because of the expense. Reduction in recommended dosage rates of corrosion inhibitors again proved a false economy since maintenance and replacement costs inevitably increase when corrosion is not prevented or minimised.

(f) Problems with the electrodialysis water desalination plant at North West Cape lead to an examination of the membranes used in the units and of resins similar to those constituting the membranes.

These tests indicated that the operational difficulties resulted from the use of water already scale forming and likely to become more so from the pH change taking place at the membrane surface.

(g) The difficulties which face some local manufacturers when their products are used in new environments were exemplified by the breakdown of a W.A. made boiler in Malaysia. The breakdown proved to result from scale formation due to inadequate use of phosphate in the local water, the phosphate being necessary to prevent the formation of troublesome silicate and sulphate scales.

(h) The Medical Department has control of services to many hospitals. During the year our aid was sought to deal with problems at Bentley, Yalgoo, Port Hedland, Exmouth, Bunbury and Geraldton, it being necessary for our officers to visit the last two.

Demineralising or softening the water and the use of scale or corrosion inhibitors in circulating systems for air conditioning and hot water supplies, although fundamentally the solutions to most problems, provide their own problems in turn in maintaining correct practices and dosages.

2. Public Water Supplies.—(a) The introduction of fluoridation increased the work of the Division because of the statutory requirements for analyses of samples of the reticulation and because of the many additional samples which both the Metropolitan Water Supply and the Country Water Supply of the Public Works Department have had carried out to check on fluoride dosages. These amounted to approximately 3,000 samples.

Samples of the sodium silico-fluoride, which is the fluoride chemical used were also analysed to ensure that material used was of specified purity.

It had been anticipated that we would receive enquiries about defluoridating drinking water but none eventuated.

(b) The water supplies to many schools, missions and settlements in remote areas were tested for fluoride as were urine specimens where the fluoride was believed to be significant.

(c) Western Australian produced activated carbon was tested and found suitable for the removal of tastes from water supply reservoirs, but before being put into practice the affected reservoir which stimulated the enquiry was drained.

(d) Depth sampling was carried out in the second week in July to endeavour to account for the sudden increase in salinity of water from Canning Dam which was being drawn from the bottom of the dam. No stratification was detected, the temperature and salinity of the water being uniform from top to bottom. It appears that evenly spread rainfall had resulted in an increased salinity of the runoff into the reservoir. The salinity of the outlet water during the autumn months and June averaged 220 parts per million and rose to about 270 ppm for the rest of the year.

The picture at Serpentine, where the water is first run from the main dam into the pipehead dam before use, differed in that a drop in salinity occurred in the output during July and early August but there followed a rise which took the total salts to 200 ppm compared with 180 ppm in the autumn months.

Mundaring showed no major variation in salinity with a general upward trend throughout the whole year from 300 parts per million in the summer and autumn, to 350 ppm by the end of the year—the reverse of the fluctuation during 1967.

The Wellington Dam pattern was similar to Mundaring but greater in extent, the rise being from about 330 ppm in autumn up to 450 ppm by the end of the year.

(e) As part of the policy of improving facilities for tourists the National Parks Board has explored water supplies which have been tested to assess their use for drinking and washing and toilet facilities. Samples came from Jane Brook, Walyunga, Kalbarrie and Stirling Range.

(f) Apart from the routine quality checks on existing comprehensive and individual town supplies advice on water treatment was given to the Country Water Supply or local water boards or companies for—

iron removal at Boyup Brook, Brunswick Junction, Eaton and Gin Gin;

turbidity removal at Borden, Dudinin, Jerramungup, Ongerup, Ravensthorpe and Wyalkatchem;

colour removal at Denmark and Tambellup;

odour removal at Narrogin.

The quality of proposed new supplies was assessed for Dampier, Meekatharra, Mount Goldsworthy, Mount Newman, Quinns Rocks and Ravensthorpe.

3. Irrigation and Hydroponics.—(a) A sample of water from the Ord River Diversion Dam in March 1968 was first class irrigation water by all methods of assessment.

(b) Meekatharra well water which had adversely affected citrus trees was found to exceed 1,500 ppm of soluble salts and to contain over 1 ppm of boron, each of them inimical to citrus.

(c) Some bore waters from the Wiluna district were either too saline or contained boron in excess of what is satisfactory for the growing of citrus which is contemplated so that an assured water supply of sufficient purity must be a prime requirement before establishment of a commercial venture.

(d) Bore water from Rocky Pool out from Carnarvon was found suitable for both irrigation and a town supply being only approximately 300 ppm in total salts and containing 0.2 ppm only of both boron and fluoride.

(e) Bore water was to be used at Kimberley Research Station in solution culture studies of rice. Being the only assured source of supply a knowledge of its composition of nutrient and potentially toxic elements was necessary.

(f) Soak water to be used in a project to grow vegetables by hydroponics was analysed for all nutrient elements and its salinity was found to be excessive already for salt sensitive plants without the addition of fertilisers.

4. Possible Toxicities.—(a) Concern about lead content from the use of lead flashings on a tiled roof used to collect rainwater for drinking was not well founded, but lead is not a satisfactory material for use in water storage and paints containing lead pigments must also be avoided.

(b) A proposal to use water from a mineshaft at Nabawa was fortunately not proceeded with without analysis because it proved to contain 0.07 parts per million of lead which is excessive for human consumption.

(c) Three cases of deaths of exotic fish in ponds with public access were reported at Kalgoorlie, Onslow and Rivervale. High levels of toxic elements such as might have stemmed from malicious additions were not found, but contents of zinc in two instances were sufficient to kill some more sensitive fish and emphasised that galvanised fittings should not be used for fish ponds or aquaria.

ENGINEERING CHEMISTRY DIVISION

Staff

The return in March of the Chemist and Research Officer, Grade 2, B. Goodheart, from the Long Service and Study Leave in England, brought the numerical strength of the professional staff of the Division to normal.

However, the resignation in July of the Senior Chemist and Research Officer, R. Canning, and of the Chemist and Research Officer, Grade 1, R. Becher in October, depleted the professional staff again very considerably, affecting the Division's work output.

Mr. B. Goodheart was promoted to the position of Senior Chemist and Research Officer in December, two professional officer's positions still remaining vacant at the end of the year. One of the vacant Laboratory Technician's positions was filled in March, D. Moore being the successful applicant. This brought the sub-professional staff to its normal level.

During the year, the Divisional Chief, Dr. S. Uusna, attended three meetings of the Board of Management of the Australian Coal Industries Research Laboratories Ltd., North Ryde, N.S.W., of which he was a member until October, representing the Western Australian Government on the Board.

Chemist and Research Officer, Grade 1, R. Becher, attended the Chemical Engineering Conference, held in Adelaide on 7th and 8th August. Chemist and Research Officer, Grade 2, B. Goodheart, gave a talk in June to the staff of the Government Chemical Laboratories about his technical activities in England, particularly at Warren Spring Laboratories.

Equipment

In the development and improvement of equipment for beneficiation of minerals, dry methods have generally tended to be neglected in favour of wet processing.

However, the need to develop mineral resources in arid areas, as is the case in Western Australia, is attracting increasing attention.

Two new developments in this field—fluid bed heavy media separator, and the pneumatic pinched sluice—were taken up by the Division, were built and one of them tested during the year, in order to evaluate their potential for local processing problems. A pneumatic pinched sluice of 31 inch length and 2½ inch throat width was built and initial trials showed promising results. The apparatus is currently envisaged as a high throughput, low cost preconcentrator, capable of processing a wide variety of dry granular materials. Its operation is based on direct fluidisation of the dry material with air allowing the particles to separate into layers, which may then be individually recovered.

The sluice, consisting essentially of a shallow tapered trough with a porous deck and integral air box below the deck, has also been shown to be of considerable interest as a high capacity dry classifier.

The fluid bed heavy media separator, the construction of which was not finished by the end of the year, is basically also a pre-concentrator that separates the constituents of ores by exploiting differences in their densities. However, because of the limitations in the feed size of the pneumatic pinched sluice, it is believed that it will be a useful complementary equipment to the latter. Feed sizes of between 3 and 22 mesh B.S.S. can be treated effectively in the fluid bed dense media separator, whilst the sluice is capable of accepting materials from about 10 mesh to below 200 mesh B.S.S.

The design of the bench scale disc electrostatic separator, designed and built by the staff of the Division (see Annual Report for 1965), was further improved by incorporation of a vacuum system, resulting in much more efficient operation of the unit.

Projects.

From the ten projects undertaken by the Division during the year, eight, i.e., 80 per cent. were carried out as sponsored work at the request of outside interests (7) and/or on behalf of other Government Departments or other Divisions of the Laboratories (1).

The Division's two own research and development projects dealing with utilisation of State's natural resources for industrial purpose, viz. (a) utilisation of titaniferous vanadium bearing magnetite ore (gabbro) at Coates, and (b) calcination of beneficiated limesand, were carried over from the previous year, and were dealt with only during the first half of the year, the largely depleted professional staff in the second half of the year being able to cope only with sponsored work.

(1) Utilisation of Titaniferous Vanadium Bearing Magnetite (Gabbro) Deposits at Coates.

The work on this project, started in 1964 and carried over from the previous year, was continued until June, i.e., the time of resignation of the Senior Chemist and Research Officer, who was in charge of the project.

During this period, the emphasis was on the treatment of both the magnetic concentrate from original gabbro and the weathered ore, by chlorination (see Annual Report 1967).

The test carried out during 1968 can be grouped as follows:

(a) Development of a two-stage condensation system for better separation of iron product from vanadium product after chlorination of ore.

(b) Chlorination of pure vanadium oxide.

(c) Chlorination of ores with addition of vanadium oxy-chloride to the gas.

(d) Production of pellets from the ores and their chlorination.

The analysis of the materials used were as follows:—

	Magnetic concentrate	Weathered ore
	per cent.	
Total iron, Fe	58.4	26.6
Vanadium, V	0.76	0.29
Titanium, Ti	6.9	3.7
Combined water, H_2O	1.7	11.0
Moisture, H_2O	0.1	1.7
Total alkali and alkaline earth oxides	0.7	0.5

In general the equipment and procedures employed were similar to those described in Annual Reports for previous years.

(a) A special two-stage condensing system was developed for better separation of iron product from vanadium product. The first stage was designed as a condenser for separation of iron oxychloride from exit gases, whereas the second stage, in the later development, took the form of a gas-scrubbing column for removal of the vanadium component. Most of the vanadium absorption experiments were made using tetrachloro-ethylene as scrubbing liquid. Vanadium was stripped from the solvent by water or dilute acid. The results indicated that a good separation of iron product from vanadium product was possible using this type of equipment.

(b) Six experiments were carried out with pure vanadium oxide as chlorination charge. These were made in order to determine the chlorination characteristics of vanadium oxide, and to provide a quantity of vanadium oxy-tetrachloride for further experiments, described below. In the existing conditions, pure vanadium oxide commenced reacting with chlorine at approximately 550° C, and the reaction was fairly rapid at temperatures just below the melting point i.e., 690° C.

(c) In a series of experiments, magnetic concentrate was reacted with chlorine gas containing additional vanadium oxy-chloride, produced in experiments (b). The results indicated that in the presence of higher concentrations of vanadium oxy-chloride in the gases, more vanadium was retained in the chlorination residues, and also more vanadium tended to stay with the iron product. This is an indication that the extraction of vanadium from the ore would be lower using a system where vanadium oxy-chloride containing gas was re-circulated. It was considered that for this reason a gas re-circulating system would not be attractive.

The above results and considerations led to investigations in the later stage towards development of a scrubbing system for extracting vanadium oxy-chloride directly from the exit chlorine gas, described under (a), even at the low concentration of vanadium compounds normally present.

(d) For the series of chlorination tests with pelletised ore, a number of different types of pellets were prepared from ores ground to minus 100 mesh size. Small batches of up to 300g were made in a bench-model pelletiser from both types of ore and their mixtures, with and without the addition of sodium chloride. The pellets were dried at 100° C and then heated for two hours or more on flat trays in an air muffle furnace at temperatures ranging from 450° to 900° C. All pellets were reasonably hard and strong, and could be handled without dusting.

A short series of systematic tests was made to determine the effect of process variables on the chlorination of pellets. This work was, however, not finalised, owing to the resignation of R. Canning, and needs further investigation. The best selectivity was obtained using pellets roasted in air at 900° C in the presence of added sodium chloride.

Summarising, it might be said that the development of a suitable two-stage condensing system has made it possible to achieve acceptable seperations of iron and vanadium from each other by chlorination and fractional condensation.

Results tabulated below can be taken as fairly typical for the series of experiments under review.

Table 5

Chlorination of minus 35 mesh magnetic concentrate in the Alundum boat

Weight of charge	10g
Chlorination temperature	850°C
Time of chlorination	4½ hours
Chlorine flow rate	400ml/min.
Degree of attack of the charge	100 per cent
Distribution of iron, per cent of charge content—	
Iron product	99·8
Vanadium product	0·05
Distribution of vanadium, per cent of charge content—	
Iron product	less than 2
Vanadium product	more than 97
Ratio of vanadium to iron in iron product	less than 0·0003
Ratio of iron to vanadium in vanadium product	0·3

The vanadium product still contained some iron as a major impurity, but at this level, the seperation could be effected by precipitation of vanadium oxide from acid solution.

The suggested recycling of vanadium oxychloride in order to build up the concentration of vanadium in the gases and hence make it easier to be recovered was shown unlikely to be attractive. However, scrubbing of vanadium oxy-chloride from exit chlorination gases with tetrachloroethylene, or a similar solvent, showed great promise as a means of vanadium recovery without recirculation of gases.

Experiments with pelletised ore, particularly with pellets made from magnetic concentrate and weathered ore in proportions most likely to result from mining at Coates, showed much promise.

However, more information is required, and will be sought during the next year.

(2) Calcination of Beneficiated Limesand

As pointed out in the Annual Report for 1967, responding to the upsurge of interest in local industrial circles towards the manufacture of high grade lime from local calcareous sand, investigations into calcination of this sand, beneficiated by electrostatic separation of silica from it, was resumed at the end of 1967 with the view of developing a suitable economic process based on raining bed techniques.

Preliminary studies were made using "cold models", the equipment being constructed of steel and perspex. In particular, the dependence of solids entrainment on superficial gas velocities in the shaft, pressure drops, time of solids retention in the unit, the effect of the ratio of the restricted shaft cross-sectional area to that of the unrestricted area, etc., were studied at a predetermined solids to gas ratio, calculated from the conditions of sand calcination at a temperature of 1000° C.

The old experimental entrained bed calciner (see e.g. Annual Report for 1962) was dismantled, and a new experimental raining bed calciner erected to the design of the Division's staff. The calciner consists of a 4½ in. x 4½ in. x 15 ft. limesand preheating shaft, an 8 in. x 8 in. x 12 in. calciner proper, and 4½ in. x 4½ in. x 5 ft. lime cooling zone. The overall height of the unit, excluding limesand feeding device, cyclones, etc., on the top, and lime collecting bin with necessary valves, etc., at the bottom, is thus 21 ft. It has been installed within the framework of the pilot retort for carbonisation of Collie coal, built in 1955-56.

For reasons of simplicity of operation, the new calciner was designed to be fired with town gas, although the commercial unit is intended to be fired with oil.

Owing to the shortage of professional staff, it was not possible during the year to put the unit into operation for limesand calcination. However, a couple of exploratory tests were run to determine the usefulness of the unit for oxidising ilmentite. The time of retention of ilmenite achieved in the unit was up to 3 minutes, and the degree of oxidation was found to be up to 50 per cent. at a temperature in the calciner of around 1,100° C.

Trials with the calcination of beneficiated limesand will be started as soon as the position regarding the professional staff at the Division improves.

(3) Hydrometallurgical Treatment of Nickel Sulphide Ore

Investigations into the possibility of recovery of sulphur and nickel from a nickeliferous pyrrhotite ore, containing about 1 per cent. of nickel, by using hydrometallurgical treatment, was commenced on the request of outside interests in the second half of 1967, and were finalised in the first quarter of the year under review.

(4) Testing of Two samples of Quicklime

Investigations into certain properties of quicklime were requested by a local industry, and were carried out on similar lines to the evaluations made for the same company in 1966.

(5) Calcination of Special Cement Meals for Production of Cement Clinker

At the request of a local firm, calcination of several trial mixes were carried out in the Division's rotary kiln under various conditions, for evaluation of mixtures for the production of cement.

(6) Heap Leaching of Copper Ore

The Division was requested by a local firm to conduct investigations into leaching oxidised copper ore samples with dilute sulphuric acid for production of bluestone for agricultural purposes.

The preliminary bench-scale investigations were followed by leaching of the ore in heaps weighing up to 2 cwt. Bluestone was recovered by crystallisation.

(7) Upgrading of Ilmenite

At the request of a firm, a sample of Western Australian ilmenite was processed on the bench scale to establish its characteristics as a raw material for upgrading by the process developed by the Division.

Following this work the Division was asked by the same Company to carry out a comprehensive evaluation of operating conditions for the upgrading of their ilmenite. This work was still in progress by the end of the year.

(8) Size Analysis of Seed Gypsum

Size analysis of 44 samples of seed gypsum, which was somewhat difficult to treat, was carried out at the request of a local firm.

(9) Treatment of Silver Halide Mineral Tailings

This work was initiated on the request of the Mineral Division of the Laboratories and was still in progress at the end of the year.

Consultative Service

During the year advice was given and discussions were held on a wide variety of subjects including: production of table salt, roasting of siderite (iron carbonate) ore, effluent problems at Laporte Titanium pigment works at Bunbury, production of kyanite from local deposits, caustic leaching of copper ores, escape of nitrous fumes from leaching columns of a local industry, concentration of tin ores from silica-clay mixtures or conglomerates, use of surfactants in mineral dressing and iron ore pelletising, manufacture of bluestone.

Visitors

Among the visitors to the Division during the year were:

- Dr. D. S. Flatt, Warren Spring Laboratories, Great Britain
- Dr. Ing. M. Pietsch, Lugi Chemie & Mitteuwesen, Germany
- P. Dixon, Acting Director of AMDEL, Adelaide.

FOODS, DRUGS, TOXICOLOGY AND INDUSTRIAL HYGIENE DIVISION

The work of this Division in 1968 dealt with samples submitted chiefly by the Departments of Agriculture, Police and Public Health. Lesser numbers were received from the Milk Board of Western Australia, the Public Works Department and the Swan River Conservation Board, and the usual variety of miscellaneous work was performed for other Departments and the general public.

Staff numbers fluctuated during the year. One technician resigned, while another technician and two chemists transferred to other positions within the Service. Two chemists and two technicians were added to the staff, but at the end of the year vacancies for two chemists and one technician had not been filled.

3,547 samples were received during the year being a decrease of approximately 21 per cent. on the number received in 1967.

A broad outline of the variations in numbers during the period 1963-68 is indicated in Table 6 (selected sample groups):

Table 6

Class	1963	1964	1965	1966	1967	1968
Foods—						
Total	656	773	720	1,084	796	454
Milks	382	604	588	865	699	367
Exhibits—Alcohol	378	433	458	484	573	647
Human toxicology	649	604	711	718	1,116	814
Industrial hygiene	233	349	262	183	297	288
Miscellaneous	1,010	883	1,053	1,163	1,260	853
Pesticides	210	175	153	132	145	154
Oil seeds	342	143	265	16	566	364
Specimens from patients....	97	166	133	147	208	158
Pollution Surveys—						
Swan River	128	145	109	110	145	157
Bunbury	48	48	48	48	48	48
Total samples received	3,279	3,511	3,611,	4,000	4,485	3,547

Table 7 shows the source and condensed decription of samples received during 1968.

Table 7

FOODS, DRUGS, TOXICOLOGY AND INDUSTRIAL HYGIENE DIVISION

	Agriculture Department	Fisheries & Fauna Department	Hospitals	Labour Department	Milk Board	Mines Department	Police Department	Post Master General	Public Health Department	Public Pay	Public Works Department	Swan River Conservation Board	Other Commonwealth Departments	Other State Departments	Various	Total
Food—																
Apples	14	....	....	....	....	....	....	....	....	....	....	....	....	....	....	14
Fruit juices	....	....	....	....	....	....	1	....	9	....	....	....	....	....	....	10
Meat-minced	....	....	....	....	....	....	....	....	20	....	....	....	....	....	....	20
Milk	11	....	....	....	285	....	....	....	71	....	....	....	....	....	....	367
Various	2	....	1	....	....	....	3	....	33	1	....	....	....	3	....	43
Industrial Hygiene—																
Air	....	....	....	....	....	18	....	....	10	....	....	....	....	....	....	28
Blood	....	....	....	....	....	....	....	....	12	1	....	....	....	....	....	13
Dust	....	....	....	....	....	10	....	....	1	....	....	....	....	....	....	11
Urine	....	....	2	42	....	....	....	....	32	132	....	....	4	4	....	216
Various	....	....	....	....	....	2	....	....	17	....	....	....	....	....	1	20
Miscellaneous—																
Baits	81	....	....	....	....	....	28	....	1	1	....	....	....	....	....	111
Drugs	....	....	4	....	....	....	39	....	....	....	....	....	....	....	....	43
Linseed	362	....	....	....	....	....	....	....	....	2	....	....	....	....	....	364
Pesticides	74	....	....	....	....	....	....	4	3	....	73	....	....	....	....	154
Water	....	....	....	....	....	....	....	....	2	3	....	....	....	....	....	5
Various	30	11	1	1	....	10	60	6	19	13	1	1	4	18	1	176
Pollution—																
Effluent	....	....	....	....	....	4	....	....	4	4	....	11	....	....	....	23
Maritime	....	....	....	....	....	....	4	....	....	....	....	....	....	....	....	4
Surveys—																
Bunbury	....	....	....	....	....	....	....	....	....	....	48	....	....	....	....	48
Ord River	....	....	....	....	....	....	....	....	....	....	55	....	....	....	....	55
Swan River	....	....	....	....	....	....	....	....	....	....	....	157	....	....	....	157
Toxicology—																
Animal	32	....	....	....	....	....	4	....	....	10	....	....	....	....	....	46
Human—																
Sobriety	....	....	....	....	....	....	247	....	....	58	....	....	....	....	....	305
Specimens from patients	....	....	53	....	....	....	....	....	93	12	....	....	....	....	....	158
Toxicology	....	....	....	....	....	....	785	....	29	....	....	....	....	....	....	814
Traffic death	....	....	....	....	....	....	341	....	1	....	....	....	....	....	....	342
Total	606	11	61	43	285	44	1512	10	357	237	177	169	8	25	2	3547

Foods

454 samples of food were received for examination; 285 of these were samples of cows milk submitted by the Milk Board of Western Australia for checking against the chemical standards for quality prescribed by Milk Act Regulations. 3.8 per cent. of these samples contained less than the legal minimum of milk fat (3.2 per cent.), and 40 per cent. contained less than the legal minimum of solids not fat (8.5 per cent.), while 40 per cent. of the samples also failed to comply with the legal standard for freezing point of milk (0.540 degree Centigrade below zero). The proportion of samples which failed to comply with the standards for fat and freezing point is practically the same as in 1967, but shows a marked improvement in respect of solids not fat figures (40 per cent. failing to comply as compared with 52.5 per cent. in 1967).

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	0.3
3.00-3.19	3.5
3.20-3.49	23.9
3.50-3.74	14.7
3.75-3.99	11.6
4.00-4.99	40.4
More than 4.99	5.6
	100.0

Milk Solids not Fat

Per cent. in sample	Per cent. of total samples
Less than 8.00	0.7
8.00-8.24	10.2
8.25-8.49	29.1
8.50-8.74	38.6
8.75-8.99	17.9
More than 8.99	3.5
	100.0

Freezing Point

Degrees C below zero	Per cent. of total samples
Less than 0.510	nil
0.510-0.519	0.3
0.520-0.529	4.6
0.530-0.539	35.1
0.540-0.550	52.3
More than 0.550	7.7
	100.0

In presenting the above figures it is emphasised that these were Inspectors' samples for which there was *prima facie* evidence of non-compliance with legal standards.

71 samples of bottled milk from metropolitan and country treatment plants and 11 samples from individual dairy herds were analysed for residues of chlorinated hydrocarbon pesticides. There was no significant difference in the analyses of the two groups of samples, the figures for which are shown in the following table:

Pesticide Residues in Milk

Concentration parts per million	No. of samples Dieldrin	D.D.T. etc*
0.008	1	
0.006	1	1
0.005	2	1
"less than 0.005"		80
0.004	1	
0.003	8	
0.002	15	
0.001	36	
less than 0.001	18	
	82	82

* includes D.D.E. and/or D.D.D.

Further work was carried out by the Horticulture Division of the Department of Agriculture on the control of "scald" in apples held in cold storage and samples of apples which had received experimental treatments with diphenylamine and ethoxyquin were submitted for analysis of the skin and flesh of the treated fruit.

Because of the low figures for ethoxyquin obtained on analysis, a sample of Granny Smith apples was subjected to similar experimental "dip" treatments in the laboratory, and the residues remaining on the fruit after storage at 60° F were determined at progressive intervals. A significant concentration of ethoxyquin was detectable 12 weeks after treatment.

Samples were submitted by the Infant and Pre-School Services of the Public Health Department to investigate the possible deterioration or insufficiency of ascorbic acid in fruit juices and fruit juice syrups. Analysis indicated that for most samples, the analytical figure agreed with that claimed on the label.

Three samples of imported canned tomatoes of somewhat "shop soiled" appearance were examined for the Public Health Department.

The first can was normal and its contents in reasonable condition apart from the fact that several of the seeds showed signs of germination, the young shoots being clearly visible.

The second can was badly distorted or "blown" due to pressure of carbon dioxide gas. The non-lacquered portions of the can showed signs of acid-etching, while the contents were fermenting and disagreeable in odour.

The third can showed some external "springiness" but no head-space gas was detected. The contents were in reasonable condition apart from the presence of a dead larva amongst the pulp and seeds.

Other varied samples of imported canned foods included meat, fish and fruit. Although in some instances the labelling could have been improved, only one sample contravened Health regulations in that it contained an artificial colouring not permitted in this country.

Miscellaneous samples of food products received and examined during the year, included—

(1) home bottled fruit which developed an unpleasant flavour, considered to be due to microbial action;

(2) cool drink and baby food for identification of foreign matter;

(3) imported plastic drinking straws examined for the presence of anti-oxidants;

(4) rye flour, found to contain a sufficient proportion of wheat flour to affect an allergic patient;

(5) samples of brandy and whisky which had been adulterated by the addition of water.

Human Toxicology

Exhibits were received from approximately 400 cases of sudden death which were the subject of police investigation. Nearly 200 cases were as a result of traffic accidents, while 140 cases, comprising 707 exhibits, were submitted for examination for poisons or other physiologically active drugs.

In 41 cases no poison or drug was detected, whilst in 99 cases a poisonous substance or drug was identified on analysis. In several instances the concentration of drug was very low and its toxicological significance uncertain. Details are listed in Table 8:

Table 8

Poison or Drug	No. of cases
Carbon monoxide	33
Pentobarbitone	35
Amylobarbitone	18
Quinalbarbitone	5
Phenobarbitone	3
Carbromal	6
Methaqualone	3
Metasystox	3
Glutethimide	3
Cyanide	2
Salicylic acid	2
*Various (one of each)	13
Negative	41

* Barbitone, chloral, chlorpromazine, dibenzepin, dichloralphenazone metabolites, ethyl chloride, kerosene-pyrethrum "fly spray", nitrazepam, prominal, salicylamide, strychnine, thioridazine, xylene.

In 52 of the 107 cases where a sample of blood was available, alcohol was found to be present. The distribution of the analytical figure in shown in Table 9:

Table 9

Alcohol, per cent.	No. of cases
Negative	55
0.05 and less	14
0.06-0.08	6
0.09-0.14	10
0.15-0.20	13
0.21-0.25	6
0.26-0.30	3

Blood Alcohol (Traffic Deaths)

342 samples of blood and/or urine were received in connection with investigation into fatal traffic accidents. 192 of these were "post mortem" blood samples which were analysed for alcohol content as a routine procedure.

The distribution of the analytical blood-alcohol figures for the various categories of persons involved in these accidents is shown in Table 10.

Table 10

Traffic Accident Deaths

Alcohol, per cent.	Drivers	Passengers	Pedestrians
	Number involved		
Negative	63	21	11
0.05 and less	9	5	5
0.06-0.08	7	3	3
0.09-0.14	11	8	3
0.15-0.20	19	1	2
0.21-0.25	9	1	3
0.26-0.30	3	1	1
More than 0.30	2	nil	1
	123	40	29

Table 10 shows that 27 per cent. of fatally injured drivers had a blood alcohol figure of 0.15 per cent. or greater, while the corresponding figure for passengers and pedestrians was 7.5 per cent. and 24 per cent. respectively.

If the "upper limit" were 0.08 per cent., as laid down in some legislations, then Table 10 shows that 36 per cent. of the drivers had a blood-alcohol figure exceeding this limit.

Blood Alcohol (Traffic Act)

305 samples of blood were received from the Police and Local Authorities in connection with—

(a) charges of "driving while under the influence of alcohol";

(b) other provisions of the Traffic Act.

Samples included under (a) were taken from persons who on being charged with this offence, had exercised the right provided by the Traffic Act to have a blood sample taken by a doctor and submitted for chemical analysis.

Samples included under (b) were taken from persons involved in a traffic accident which caused injury requiring medical attention, and of whom it was suspected that driving ability may have been impaired by alcohol. In some cases in which samples were taken "breath analysis" equipment was not readily available, e.g., in country areas; in other cases the sample was requested by the subject, exercising his rights following a "breath analysis" test (Section 32B, (4) and (5) of the Traffic Act).

The Traffic Act stated (Section 32C (4)), that if the alcohol content of the blood at the time (of an alleged offence, or accident) is 0.15 per cent. or greater, it is *prima facie* evidence that the subject was under the influence of alcohol at that time. Amendments to the Traffic Act, which came into operation on 20th December, 1968—

(a) made the figure of 0.15 per cent. or more "conclusive evidence that the person was at that time, under the influence of alcohol to such an extent as to be incapable of having proper control of a vehicle . . . ";

(b) made it an offence to drive a motor vehicle on a road or public place, if the blood-alcohol concentration of the driver is 0.08 per cent. or more.

Of the samples analysed in 1968 under the Traffic Act not more than five per cent. were taken after 20th December, 1968. The results of these analyses are set out in Table 11 the figure being the alcohol content of the blood at the time of the accident or alleged offence, calculated as prescribed by the Blood Sampling and Analysis Regulations, 1966.

Table 11

Alcohol, per cent.	No. of cases
0.05 and less	10
0.06-0.08	10
0.09-0.14	36
0.15-0.20	121
0.21-0.25	73
0.26-0.30	42
More than 0.30	13
Total	305

In accordance with established practice, the analysis was repeated independently by another chemist when sufficient sample was available and no prior plea of guilty had been entered. 136 samples were repeated in this way, making a total of 441 analyses in connection with this work.

Table 11 shows that 249 persons, or 82 per cent. of the total, had a blood-alcohol figure of 0.15 per cent. or greater and that 285 persons, or 93.5 per cent. of the total, had a blood-alcohol figure in excess of 0.08 per cent. The proportions are very similar to those observed in 1967 which were 80 per cent. and 94 per cent. respectively.

An examination of the times at which the accident or "offence" occurred showed that the greatest number per hour occurred between 10 p.m. and midnight, followed by the period 9 p.m. to 10 p.m., then a lesser but fairly uniform number through the hourly periods 4 p.m. to 9 p.m. and midnight to 1 a.m. The distribution of these "times of occurrence" is given in Table 12.

Table 12

Time of occurrence	No. of cases
p.m.	
4-5	22
5-6	20
6-7	22
7-8	19
8-9	21
9-10	30
10-11	51
11-m.n.	48
a.m.	
m.n.-1	23
1-2	15
2-3	9
3 a.m.-4 p.m.	25
	305

Specimens from Patients

One hundred and fifty-eight samples were received under this classification. Approximately 90 samples of urine and 55 samples of blood together with a small number of gastric contents, etc., were analysed in connection with the medical examination of patients for clinical purposes as distinct from industrial hygiene and toxicology. The varied analyses performed under this classification are detailed in Table 13:

Table 13

Analysis	Number
Alcohol	4
Amphetamines	37
Arsenic	8
Barbiturates	31
Copper	15
Dieldrin	9
Dilantin	2
Glutethimide	2
Lead	43
Mercury	4
Phenothiazine derivatives	4
Strychnine	3
Thallium	3
*Various (one of each)	10

* Carbon monoxide, carbromal, DDT and derivatives, diazinon, fluorine, meprobamate, methanol, methaqualone, methyl phenidate, thioridazine.

Animal Toxicology

Twenty-three exhibits were received from seven animal post mortem examinations. In three cases strychnine was detected, three cases were negative, and in one case the presence of diquat was suspected but the level was too low for positive confirmation.

From 28 suspected poison baits, strychnine was detected in six; the remainder were negative.

Work was continued for the Vermin Branch of the Department of Agriculture on the distribution of strychnine in prepared baits during the mixing process and 81 samples of dingo baits were submitted for analysis.

Two samples of animal feed suspected of of seriously affecting the health of experimental laboratory animals were submitted by different Institutions and analysed for fluorine content. A very great difference was found in the concentration of fluorine in the two feeds.

Industrial Hygiene

Two hundred and eighty-eight samples were examined during the year in connection with industrial hygiene investigations.

One hundred and ninety-five of these were specimens of urine from workers exposed to suspected lead hazard. Analysis for lead was carried out to assist clinical diagnosis or to provide a "screening" to exclude the possibility of undue exposure.

Of these specimens, 139, or 71.3 per cent. contained not more than 0.08 parts per million (milligram per litre) of lead (as Pb), 23.1 per cent. contained 0.09-0.15 parts per million, 3.6 per cent. contained 0.16-0.20 parts per million, and 2 per cent. contained more than 0.20 parts per million.

Other specimens examined in connection with possible exposure to hazardous materials included—

(1) Thirteen samples of urine analysed for arsenic from pest control operators, etc.;

(2) Seven samples of blood and 13 of urine analysed for dieldrin, and 10 samples of blood analysed for D.D.T., also from pest control operators;

(3) One sample of blood, for cyanide, and nine samples of urine, analysed variously for mercury, manganese, fluorine and pentachlorophenol.

Inspections were made of working conditions in various factories, and samples of air and/or dust were analysed for—

(1) Lead, in assay offices and a battery factory;

(2) Formaldehyde, in a factory using urea formaldehyde resin;

(3) Arsenic, in a plant manufacturing arsenical "dipping" fluids;

(4) Carbon monoxide, in a location liable to contamination from motor vehicle exhaust fumes

Thirteen inspections were carried out as a result of complaint of hazardous working conditions in the holds of cargo ships.

These were the result of leakage or spillage due to broken containers of various chemicals such as ethyl acrylate, xanthates, sodium fluosilicate, methylene chloride and other miscellaneous organic chemicals. "On the spot" assessments were made of the potential hazard in each case and advice given as required on ventilation and other protective measures necessary to ensure safe working conditions.

Pollution Surveys

Swan River.—Regular surveys of the Swan River were continued in 1968 when 150 samples of river water were collected and analysed for the Swan River Conservation Board. Seven "non-survey" samples were also examined to investigate specific instances of suspected pollution.

Nineteen samples of effluent from specific factories were analysed 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 surveys of the water in Leschenault Inlet at Bunbury, and 48 samples of water were collected and analysed in the surveys of February and July, 1968.

Ord River.—55 samples of water from the Ord Irrigation Drainage System were submitted by the Public Works Department. These were analysed as a check on the possible presence of traces of pollution from the pesticide sprays used in that area.

Maritime.—Only 4 samples of suspected oil were received during 1968. These were fluids alleged to have been discharged from ships into waters under the jurisdiction of the Fremantle Port Authority and were submitted for analytical confirmation that they were in fact oil or similar substance.

Miscellaneous

Pesticides.—154 samples classified as pesticides were received for examination during the year. The numbers and types of these samples are listed in Table 14.

Table 14.

Type of Pesticide	No. of Samples.
Aldrin (concentrate)	21
Aldrin (diluted emulsion)	41
Dieldrin (solid)	7
Dieldrin (concentrate)	9
Malathion (concentrate)	7
Weedicide concentrates—	
2,4-D amine	14
2,4-D ester	27
2,4,5-T ester	6
Various	22

The samples of aldrin concentrate and diluted emulsion were examined for the Architectural Division, Public Works Department in connection with "white ant" preventive treatments being applied to building projects, where sampling was carried out as a check on the materials being used for treatment purposes.

Fourteen samples of soil were also analysed for aldrin and/or dieldrin to determine the efficiency of application in specific cases.

Seven samples of technical dieldrin and 9 of dieldrin concentrate were analysed for conformity to the specifications of the Biological Services Division of the Department of Agriculture.

The increase in the number of samples of 2,4-D type weedicide observed over the past few years was maintained during 1968 and 47 samples were received from the Weed Control Branch and checked for quality of the concentrates.

Similar checks for quality were carried out on 7 samples of malathion concentrate used in connection with programmes of fruit fly control.

Criminal.—Tablets, chemicals and miscellaneous materials were examined during the year for the Police Department as a result of the activities of the C.I.B. Drug Squad. Methyl amphetamine was the drug most frequently encountered, but cannabis, L.S.D., and mescalin were also detected.

The dried seed capsules of a suspected opium poppy plant were found, on analysis, to contain morphine equivalent to 0.1 per cent. opium of British Pharmacopoeia standard.

Two samples of beer contained remains of a sleeping tablet and capsule respectively, but in the case of other exhibits such as sherries, chocolates and cough mixture no evidence of harmful adulteration could be detected.

In connection with the alleged misrepresentation of an exterior coating for houses, work was continued in 1968 at the request of the Court in order to clarify contentious points which had arisen during Court proceedings.

Miscellaneous samples included charred remains from fires, putty and glass fragments from a "breaking and entering" and exhibits from suspected malicious interference with a marine engine, a car, and trees.

General.—362 samples of linseed from the Department of Agriculture were analysed for oil and moisture contents in further work in connection with the Department's variety selection trials.

Samples of apple packing materials were examined for urea-formaldehyde resins to exclude the possibility that this was the cause of "spotting" in stored apples, as had been observed overseas.

Samples of paint thinners and curing agents which had given rise to complaints of illness when used in confined spaces, were analysed to determine the identity of their volatile components. Benzene was not detected in any sample, but all contained commercial xylene together with butyl alcohol and/or methyl ethyl ketone.

Eighteen samples of mine air were analysed for carbon monoxide, carbon dioxide and oxides of nitrogen in connection with further investigations into pollution of underground air by exhaust gases from diesel-powered equipment.

Samples of tallow were analysed to check their quality against trade requirements, and samples of tar oil submitted by the Main Roads Department were examined for compliance with the appropriate Australian Standard Specification.

A child's plastic toy doll, the subject of complaint on other grounds, was found to comprise eight distinct components. One readily ignited and burned. Five of the eight components contained nitrate in varying amounts, and the highly flammable portion was identified as cellulose nitrate. There was no warning label as required by the Toxic and Hazardous Substances Regulations.

Only five samples classified as explosives were submitted for various examinations. These included complete analysis, identification of specific constituents and testing for compliance with accepted standards.

Four samples of compressed air in cylinders, for use in underwater swimming were examined for compliance with specifications of the Royal Australian Navy.

Concern over the possible fading of ball-point pen inks when used on legal documents resulted in a systematic investigation of 31 different brands or types being tested. It was found that approximately half the samples faded to some degree on exposure to diffuse light, while in the more drastic test of exposure to sunlight or ultra-violet light, there were very marked differences between the samples after only a short period of time.

Miscellaneous samples submitted for examination included—

(1) a Breathalyzer for checking and servicing;
(2) building materials for fire-testing;
(3) clothing for identification of material in connection with suspected false trade description;
(4) poultry feed for analysis for pesticide residues;
(5) Identification of the constituents of marker materials used for check on suspected illegal practices.

The normal range of 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.

The Divisional Chief, Mr. N. R. Houghton, attended the meeting of the Food Analysts Sub-Committee of the National Health and Medical Research Council held at Hobart in June.

Mr. F. E. Uren attended the Annual Conference of Scientific Officers engaged in Industrial Hygiene, held at Sydney in August.

Mr. V. J. McLinden attended an inaugural interstate Conference on Toxicology, held at Melbourne in November.

A paper by Mr. R. C. Double. "The Infra-Red Determination of Dithianon," was accepted for publication by the Association of Official Analytical Chemists, U.S.A., and is expected to appear in the Journal of the A.O.A.C., May, 1969.

FUEL TECHNOLOGY DIVISION

The Division had 100 registrations of investigations and samples assigned to it in the year. The National Coal Research Advisory Committee project, viz. "Investigation of the mechanism of the reaction of solid carbon with metallic oxides in connection with the direct reduction of ores with coal", Lab. No. 11926/65, has continued during the whole year. A full report of Part 1. of the investigation entitled "Reduction with solid forms of carbon" was submitted to the Committee at the beginning of the year. The present year's work has been mainly on gaseous reduction with hydrogen and carbon monoxide as bearing on the mechanism of reduction with solid carbon, specifically as char from Collie coal, since chars always contain some hydrogen and carbon monoxide gases which appear to be the active agents of transfer of oxygen to carbon in reduction of solid metal oxide. The work was also extended to measure the reactivity of chars and other forms of carbon as this bears on reactivities in metal oxide reduction. This latter work was also submitted to the National Coal Research Advisory Committee under the title of: "Thermogravimetric determination of the reactivities of chars, coke and other carbonaceous materials". The work, as the title suggests, used the thermogravimetric method developed by the laboratory for investigations of reaction rates. The reports were well received and commented on favourably by associates on the National Coal Research Advisory Committee. The enabling grant of $10,000 for the research has been renewed for a further year. The report on "Thermogravimetric determination of reactivities of chars etc." has been accepted for publication in the English journal "Fuel".

Other work has covered a variety of samples ranging from analysis of coal sampled from working mines at Collie to a calorific value determination on dietetic apple juice. In the area of applied fuel technology, where the laboratory is uniquely equipped to help State industries, a steam-use survey was made on a laundry at one institution and the entrained drier at Capel, designed for ilmenitic sand by the Division in 1959 and which has operated successfully since, was investigated under altered and more suitable conditions than held in the past. Recommendations were made for further improvements in throughput and operating efficiency.

Table 15
COAL ANALYSES

Source	Collie Western 2	Collie Muja	Unknown (a) Recovered from drilling cores 1	2	3	4
Lab. No.	17208-17209	17207	5351-5364			
Analysis—						
Moisture	25·8	23·7	20·0	20·0	20·0	20·0
Ash	2·9	1·6	4·2	13·3	20·7	45·2
Volatile matter	29·1	30·7	33·5	28·9	24·3	17·6
Fixed carbon	42·2	44·0	42·3	37·8	35·0	17·2
	100·0	100·0	100·0	100·0	100·0	100·0
Sulphur	0·4	0·2	n. d.	n. d.	n. d.	n. d.
Calorific value, gross—						
As analysed basis	9,150	9,560	9,530	8,140	7,210	n. d.
Dry, ash-free basis	12,830	12,800	12,570	12,200	12,160	n. d.

n. d.—not determined

(a) These analyses are averages for samples which were recovered from drilling cores which have been grouped arbitrarily according to ash content. The analyses are calculated on the basis of 20 per cent. moisture content for comparison purposes.

The Chief of Division continues to serve as State representative on the National Coal Research Advisory Committee which has met three times in the past year. He is also a member of the main Committee's subcommittee on carbonisation which met once during the year. He also continued as a Mines Department representative on the Air Pollution Control Council until the end of the original three year term as provided under the Clean Air Act.

The Division's Grade I Chemist and Research Officer continues to serve as Fuel Technologist on the Scientific Advisory Committee under the Clean Air Act. There has however been no move to use through him the services of the Division for measuring and testing atmospheric pollution and it is not clear whether in the administration of the Act facilities for the testing of pollution will be bypassed completely or duplicated by the Public Health Department.

The Grade I Chemist and Research Officer also attended a conference on Combustion and Combustion Engineering organised by the Institute of Fuel (Australian Membership) at Canberra. A paper on Space Heating was presented by him on behalf of the Divisional Chief.

Coal Analyses

The analyses of coal samples set out in Table 15 were made during the year.

Dust Deposition

Determinations of dustfall in the Metropolitan Area on the basis of monthly collection from industrial and residential sites were made during the year as set out in Table 16.

Table 16
DUST DEPOSITION 1968

Test Position	Rate of Deposition Tons per Square Mile per Year — Summer Max.	Summer Av.	Summer Min.	Winter Max.	Winter Av.	Winter Min.
Industrial—						
East Perth	290	260	210	340	280	170
Rivervale	310	280	170	200	130	60
Main thoroughfare—						
Laboratories (a)	420	260	130	140	120	110
Residential—						
Redcliffe	70	55	30	50	38	30
Wembley	60	40	20	70	33	15

(a) Towards the end of 1968 these deposition rates were increasing because of building operations close to the gauge.

Thermogravimetric Work on Chars Relative to Reduction of Iron Oxide in Ilmenite

The work on the reduction of metal oxides is a fundamental research aimed at improvements in the established techniques for the reduction of iron oxide in ilmenite to metallic iron to enable the iron thus produced to be extracted by hydrometallurgical methods. The investigation which is now more than three years in being has logged over 600 experiments all based on the thermogravimetric method for measuring reaction rates in granular beds which has been evolved in the Division. Measurements of surface area of chars used in reductions have also been made for us by C.S.I.R.O. Coal Research Section of Mineral Chemistry Division.

The work completed to the present time of reporting has been reported in full to the National Coal Research Advisory Committee and copies of the full reports are available for any enquirers interested in the field.

The general finding is one which has been stated in previous reports that hydrogen contained in coal and in chars is an intermediary between metal oxide and carbon in converting oxygen from the oxide into carbon dioxide and carbon monoxide as products of reduction. The handing on process can also take place from water formed in reduction to carbon monoxide which forms carbon dioxide to some extent to satisfy the water gas equilibrium—

$$H_2O + CO \rightleftharpoons H_2 + CO_2$$

The following Table summarises experience of the effectiveness of reduction by chars with their reactivity towards carbon dioxide, their surface area and their hydrogen content. The reducing index towards the iron oxide in ilmenite is based on the per cent. reduction of iron oxide by any char used in a ratio of 30 parts by weight of char to 100 parts by weight of oxidised ilmenite at a temperature of 1,000°C for a reduction period of approximately 120 minutes.

Table 17

CHARACTERISTICS OF CHARS USED IN REDUCTIONS OF ILMENITE

Reductant	Reducing Index towards ilmenite per cent	Reactivity at 1,000°C g. per min	Surface Area m^2 per g.	Hydrogen Content per cent
Spül Char	95·3	0·107	382	2·0
Reject Char	47·7	0·105	478	0·5
Retort Char 600°C	74·8	0·062	372	2·7
Retort Char 900°C	46·7	0·059	300	0·5

The spül char was made from Collie coal by carbonising to 700° C in hot circulating gases of the composition of mixed water-gas and coal gas. This gas in the course of circulation also cooled the char and in the whole process of carbonising and cooling would react with the char to increase its reactive surface area, at the same time leaving it with a considerable hydrogen content characteristic of the relatively low 700° C carbonisation temperature. It is seen that the reactivity to carbon dioxide is high and the surface area is considerable. The combination of reactive surface area and high hydrogen is associated with a high reducing index.

The reject char was unreacted char discharged from a rotary kiln reduction of ilmenite using raw coal as the reductant. The char has a high surface area and an associated high reactivity to carbon dioxide but its hydrogen content is low as can be expected from the temperature to which it was subjected. Its reducing index is poor and this can be ascribed to the low hydrogen content.

The 600° C char was made from Collie coal by carbonisation in a closed retort. The hydrogen content is high, characteristic of the low temperature of treatment. The surface area is also high but the reactivity is low. The reducing index to ilmenite is only moderate.

The 900° C char was made again by closed carbonisation. The hydrogen is low, characteristic of the higher temperature of treatment. Surface area is moderate but reactivity to ilmenite is poor.

The general conclusion is that a combination of reactive surface area and hydrogen is necessary to obtain effective reduction. This surmise was proved by passage of hydrogen at low rates through mixtures of oxidised ilmenite with only 20 parts of reject char per 100 parts of ilmenite. A reduction of 100 per cent. was obtained in 120 minutes. Similar results were obtained using limited amounts of raw Collie coal with hydrogen passage.

The practical outcome of these findings, if any, is still being examined relative to use of blue-water-gas instead of hydrogen as a reductant since blue-water-gas is readily made from Collie coal on a basis of production which was examined by the Division some twenty years ago. Whether the accumulated experience of the Division can be put to ultimate good use in this way may possibly be known in the course of continued research. Impending retirements from the Division may however determine otherwise.

INDUSTRIAL CHEMISTRY DIVISION

Introduction

Forty-five samples were allocated to the Division during the year, a decrease on previous years. Of these, 23 were "Public Pay," the highest proportion of this classification of sample for several years. This increase is encouraging, as it reflects an increasing awareness in chemical and allied industries of the facilities and technical assistance available in this Division. Of the 23 Public Pay samples, four were sponsored investigations for local companies wishing to develop new processes or improve existing ones. There was a significant decrease in the number of paints, plastics and building materials examined, largely due to the ability of the staff to provide the required information from previous work and knowledge in these fields, thus eliminating the necessity for analyses or testing programmes. The Division's advisory and consultative work continued to function, advice being given on chemicals, chemical processes, equipment, plastics, paints and building materials.

Staff

1. Mr. A. Reid, Chief of the Division, died on 22nd May, 1968 after an illness of some four months. Dr. E. B. J. Smith was appointed in his place and is due to take up duty early in 1969.

2. Mr. R. I. McKinnon was promoted to the position of Chemist and Research Officer Grade 1 as from 17th January, 1968.

3. Mr. D. J. Ingraham and Miss B. M. Collingwood were appointed as Chemists and Research Officers during the year.

4. Mr. F. F. Chafin lectured in Glass Reinforced Plastics at the Carlisle Technical School.

Classification of Work

(1) Routine:
- (a) Building Materials.
- (b) Plastics.
- (c) Miscellaneous.

(2) Assistance to Industry.

(3) Investigational.

(4) Consultative.

(1) *Routine*

(a) Building Materials.—Several samples of building materials were examined during the year, including paints, service failures for building contractors, and staining of brickwork and fibrous plaster.

A sample of P.V.C. covered metal was tested for colour retention and durability. Although the P.V.C. layer was rapidly discoloured by exposure to ultra violet light, no embrittlement or other deterioration was observed, and the adhesion to the metal was only slightly affected. The sample was deemed suitable for interior applications, and exterior applications in cases where colour is unimportant. A second sample of the same material, this time specified as exterior grade, was examined and it too was found to be rapidly discoloured by ultra violet light.

Stains on the ceiling of a remodelled building were found to be caused by bituminous material from a demolished cold store on the floor above. Recommendations were made for the treatment of the stain and the prevention of its recurrence.

Because of the frequency of enquiries about stains on fibrous plaster walls and ceilings, a comprehensive report covering diagnostic techniques and remedies was prepared. This report, which covers all types of stains so far encountered since the Division has investigated this type of problem, was prepared for the guidance of Divisional staff and the building industry generally. Quite frequently, as was the case with one complaint investigated during the year, the stain is the result of two or more causes.

A case of multiple staining of white calcium silicate brick work was investigated. One stain was easily removed but the other proved resistant to all standard stain removing techniques, and could only be removed by abrading away the discoloured surface.

Two samples of gloss white paint were examined on a comparative basis to ascertain why one was inferior. The low gloss and poor hiding power of the inferior paint were found to be due to the coarseness of the pigment, indicating that the manufacturer is possibly only mixing his paints, rather than following the correct procedure of grinding the pigment into the vehicle.

One sample of "trowel-on" plastic floor coating was examined for comparison with materials which had been tested some years before, but which are no longer commercially available in this State. The new sample was found to fall short of the older material in many respects.

The failure of a wood mosaic floor to adhere to a concrete substrate was investigated. The adhesive was satisfactory, the concrete moisture was below the recommended maximum, and the failure was attributed to the chalky nature of the concrete.

A sample of bituminous aluminium paint was examined for suitability on roofs in an industrial atmosphere. It was irradiated with ultra violet light, and exposed to high concentrations of gases normally found in small amounts in the atmosphere in industrial areas. The paint was found to be only slightly affected.

Two samples of hardened concrete were examined for the presence of lignosulphonate type retarders, and eleven samples of concrete ingredients (cement, sand, aggregates, and water) were analysed for triethanolamine—a concrete additive sometimes added to give a high early strength.

(b) Plastics.—Although this year saw a reduction in the number of plastics samples received it also saw an improvement in the techniques for examining and commenting on plastic materials. With access to an infra-red spectrophotometer and a good knowledge of the properties of plastic materials, the staff were able to identify plastics and similar materials and predict their suitability for a known environment from the known properties of the particular plastic or blend of plastics. Thus a rapid answer could be given and long performance tests were avoided to some extent. In many cases a spectrum was run on a film cast from a solution of the plastic in a solvent, but where the thermosets were examined, an infra-red spectrum of the pyrolysate (product of destructive distillation) was used to identify the substance.

Two samples of plastic electrical components were identified. Both were heavily glass filled to give them mechanical strength. One resin was a styrene modified polyster, the other was an anhydride cured epoxy resin. Both these resins were thermosetting and the latter proved difficult to identify. Anhydride cured epoxy resins are noted for their good dielectric properties.

A plastic fan blade intended for use at high air temperatures was examined for suitability. The plastic was identified as polystyrene, which has a heat distortion temperature higher than the maximum expected service temperature. Physical tests for creep and distortion confirmed suitability.

A prototype of a glass reinforced plastic septic tank was inspected for the State Housing Commission. Several faults in design and construction were evident, but it was considered that with modifications these articles could be produced locally at competitive cost.

Five filament wound anode encapsulation tubes intended for use in the electrolytic protection of structures at North West ports were examined for hardness. They were of interest to the Division because the figure specified for Barcol Hardness was originally chosen on advice from this Division, and was thought to be high enough to give adequate service, yet not too high for the producer to meet.

(c) Miscellaneous.—A sample of wire drawing lubricant was examined for the Public Works Department to see if it would have any deleterious effects on wiring when in long term use. It was found to be an aqueous emulsion of paraffin wax, which being a fully saturated hydrocarbon would not harden or polymerise. It was considered that the material would not bind the wiring in conduits and prevent subsequent withdrawal.

A deposit in a tube-in-shell heat exchanger from the cooling system of a large diesel engine was identified as congealed oil. In investigating its origin it was found that a large water storage tank had been newly cement coated, and that the subsequent alkalinity of the cooling water had caused the "soluble" oil to de-emulsify and deposit in the heat exchanger. Recommendations were made on removing the deposit and preventing its recurrence.

To assist the Museum to recondition the skeleton of a large blue whale, experiments were carried out on several sections of broken and eroded whale bones. A suitable system was devised and the client advised of procedure and sources of supply of chemicals.

Two samples of rubber connectors, one satisfactory and the other unsatisfactory, were examined to find the chemical difference between them. The unsatisfactory one showed indications of the presence of reclaimed or scrap rubber.

(2) Assistance to Industry

(a) Building Board Manufacture.—An investigation was carried out for a party interested in the manufacture of a light weight insulating building board from saw dust. Experiments were done to find out the most suitable and economical bonding agent to bind the saw dust particles together. To put the project on a production basis the adhesive had to have an elusive combination of properties, including rapid, but controllable setting time, thixotropy (to facilitate particle wetting), but at the same time avoiding excessive draining, and cheapness. A suitable bonding agent was found and encouraging samples of the product were prepared.

(b) Furfural from Marri bark.—This sponsored project, initiated in 1967 was completed during the year. Furfural was produced fom Marri bark by acid hydrolysis under high pressure at elevated temperatures. Yields were determined under several combinations of process variables and optimum conditions were established. The results are confidential.

(c) Plaster of Paris.—To assist a local plaster of paris manufacturer to improve his product, and enhance its export potential, three sections of the manufacturing process were investigated. These section were the washing of seed gypsum, the calcining section and the size reduction unit. Analyses were done on raw materials and products, and recommendations made on the modifications to plant and process to improve the product. Advice was also given on simplified methods of quality control suitable for use by semi-skilled staff.

(d) Vegetable Oil Extraction.—A sponsored investigation into the extraction of oil from oil-rich seeds was commenced during the year. It is proposed to establish an oilseed industry in the South West part of the State, and processing plants will be set up at suitable centres. The company intends to extract the oil by solvent extraction and separate off the protein-rich solid material. This Division is assisting by running trials to provide technical data for the design of pilot and full scale plants. Test runs have been carried out to ascertain such process variables as optimum fineness of grinding, residence time in the extractor unit, extraction temperature, methods of separation of liquid and solid phases, methods of separation of oil from solvent, solvent/solid ratio, solvent recovery, and stripping of solvent from residual meal. Many sections of the Unit Process Plant are in use on this project.

(3) Investigational

(a) Painting of Karri Timber.—Inspections of the samples under exposure were continued during the year. From the recorded observations it has been noted that thirteen of the seventy-eight systems on exposure have shown no signs of blistering, peeling, or any other defect in the one and a half years the samples have been exposed.

From the results so far obtained it appears that acrylic paints are the most suitable for karri timber for they presented almost a one hundred per cent. successful performance. It should be noted however, that although only one brand of acrylic paint was tested, it is felt that other brands would perform equally well. It is hoped that exposure testing of other brands will be carried out in the near future.

No conclusion has yet been drawn regarding the type of sawing, or the timber moisture content at the time of painting, for the most successful painting. All of quarter sawn, back sawn heart face, and back sawn bark face appear to perform equally well; while green, dry or intermediate moisture test pieces have all performed satisfactorily when coated with acrylic paints. It is not known yet whether the acrylic paints will be satisfactory for repainting. The exposure trial is continuing.

(b) Furfural from Karri Sawdust.—Work on this project was impeded by lack of equipment, but this is now to hand, and it is hoped that this project will be resumed early in 1969. It proposed to try a continuous low pressure fluid bed technique using a hot current of inert gas as a fluidising medium, thus sweeping volatiles from the system as they are formed and minimising losses due to side reactions. A heater for the fluidising gas has been designed and constructed.

(4) Consultative

A large number of enquiries was handled during the year. Not only did the enquiries vary widely in type, but they came from many different types of people. The sources of the enquiries included other Government Departments, private architects, insurance assessors, marine surveyors, medical practitioners, engineers and manufacturers.

Queries on paints and plastics were frequent, and in most cases the Division's staff were able to recommend a suitable material for a specified use and environment. The number of enquiries on reasons for service failure of paints and plastics dropped, and there was an increase in the number of enquiries on the properties and applications of these materials from engineers, architects and builders. It is encouraging to note that these people are consulting the Division before specifying materials, rather than waiting for a failure to occur, then requesting a solution to the problem.

There were numerous requests for sources of supply for various chemicals, and enquiries on alternatives and substitutes for expensive or unobtainable materials. A comprehensive index of local agents and suppliers enable the majority of these enquiries to be attended to satisfactorily. Intending chemical manufacturers were advised on raw materials, manufacturing techniques, equipment and possible markets. In some cases, the ideas put forward were either technically or economically unfeasible and the parties concerned were advised to discontinue their projects.

MINERAL, MINERAL TECHNOLOGY AND GEOCHEMISTRY DIVISION

General

A total of 3,910 samples was received during the year, from the following sources:—

General Public (free)	1,626
General Public (pay)	780
Mines Department	1,274
Other Government Departments	230

The source and type of sample are shown in Table 18.

The number of samples received into the Division in the past six years is shown in the following Table.

	1963	1964	1965	1966	1967	1968
Public pay	744	796	741	1,154	1,491	780
Public free	837	879	3,210	1,757	2,054	1,626
Government Departments	1,097	720	887	928	809	1,504
Total	2,678	2,395	4,838	3,839	4,354	3,910

The public samples show a reduction when compared with the previous year, pay samples received being 48 per cent., and free samples 21 per cent., fewer in 1968.

The increase in the number of samples from Government Departments is due almost entirely to the growth of geochemical activities within the Geological Survey Branch.

Staff

Staff movements this year include the appointment in November of Mr. T. Dixon, B.Sc., on completion of his studies for honours in chemistry under the cadetship system. The services of Laboratory Technician Mr. R. Tomich were made available to the Division for a short period at the end of the year.

Mr. L. J. Bateman was promoted from Laboratory Assistant to Laboratory Technician on 13th December.

Mr. R. W. Lindsey, the safety officer for the Division, attended a National Safety Council "Laboratory Safety Symposium" in August and a number of items of safety equipment have been installed. The noise hazard associated with our crushing machinery has been checked by officers of the Commonwealth Acoustics Laboratory and their recommendations implemented. A similar survey of radiation hazard has been conducted by officers of the State X-ray Laboratories.

Mr. M. Pryce continues to be the planning officer for the Civil Defence and Emergency Services and during the year has worked on a Laboratories Emergency plan and made a number of Civil Defence appointments.

In November Mr. Pryce spent several days at the Melbourne works of a commercial firm to assess the potential of some X-ray fluorescence equipment. A visit to some mineral deposits and workings in the Kimberley area was made by the Divisional Chief and in July Mr. Burns visited several Laboratories while in Adelaide on other business.

Two officers of the Division attended the Sixth Conference of Australian Crystallographers in Perth in August.

Table 18

MINERAL DIVISION

	Mines Department	Public		Public Works Department	Main Roads Department	Agri-culture Department	Various	Total
		Free	Pay					
Clay	2	9	2	....	....	1	5	19
Concrete	1	....	4	14	19	....	10	48
Dust	62	....	....	79	....	....	9	150
Metals and alloys	4	....	24	....	9	....	1	38
Mineral indentifications	104	532	97	....	....	3	1	737
Minerals and ores								
Copper	18	61	52	....	....	....	....	131
Gold ores	5	154	194	....	....	....	....	353
tails	83	....	....	....	....	....	....	83
umpires	12	....	....	....	....	....	....	12
Gypsum	....	17	4	....	....	....	....	21
Heavy sands	....	48	5	....	....	1	....	54
Iron	....	72	17	....	....	....	....	89
Lead	10	18	6	....	....	....	....	34
Manganese	1	21	6	....	....	....	....	28
Nickel	3	533	36	....	....	....	....	572
Phosphate	18	1	1	....	....	....	....	20
Rare-earths	3	1	20	....	....	....	....	24
Sand	22	....	9	....	....	....	1	32
Silver	8	5	22	....	....	....	....	35
Tantalite	2	30	39	....	....	....	....	71
Tin	9	5	39	....	....	....	1	54
Titanium	5	22	82	....	....	....	....	109
Others	64	90	83	....	....	....	....	237
Complete analyses	39	....	2	....	....	....	....	41
Geochemical analyses	781	7	....	....	....	....	....	788
Miscellaneous investigations	18	....	36	3	....	44	29	130
	1,274	1,626	780	96	28	49	57	3,910

Distinguished visitors from whom the Division has profited included Professor T. S. West of the Analytical Chemistry Department, Imperial College, London, Dr. K. Norrish of C.S.I.R.O. Division of Soils, Adelaide and Dr. Ralph Grim of New York, a world authority on clays.

Publications

During the year three Reports of Investigations were issued from the Division. These were—

R.I. No. 1 Magnesian Gaspeite and Nickeloan Magnesites from Western Australia, by R. C. Morris and R. S. Pepper.

R.I. No. 2 Accessories for use in Ore Microscopy, by R. C. Morris.

R.I. No. 3 Minor and Trace Element Distribution in Western Australian Sphalerites, by P. E. Hewson.

Equipment

The major equipment acquisition this year has been a General Electric XRD-5FII X-Ray Generator to run two X-ray tubes simultaneously for routine and specialised X-ray cameras. One of these cameras, a Stoe-Weissenberg with 2 :1 and 8 : 1 gearbox ratios for specialised powder and single crystal studies, was delivered in the latter half of the year. A Guinier-Hagg camera is also on order, with delivery expected early in 1969. These items will allow structure investigations to be done in the Division and will relieve pressure on the old Muller A.G. Generator. With the new generator, powder diffraction film patterns will be used for qualitative work and quantitative work until such time as the demand necessitates a diffractometer set up. The generator and cameras will be set up early in 1969 following completion of structural alterations to the building and supply of necessary services.

A Leitz Pradovit automatic projector was acquired for use during lectures and for general laboratory projection.

A new Nikon stereomicroscope, with polarising attachments, has proved useful for general low power examination of mineral grains and for mounting of single crystals for X-ray examination.

An Ika-Filtrax centrifugal filter has proved useful both to mineralogists in rapid filtration of heavy liquid media and clay samples and to the chemists for separation of fine suspensions.

Speed of handling of samples has been increased by the purchase of Mettler top pan balances P1000 and P1200 and a Retsch-Muhl mechanical mortar grinder.

The influx of large batches of samples has necessitated the setting up of two new sample drying cabinets and the renewal of the Braun pulveriser plates and zinc grinding laps.

Mineral Collections

One hundred and twenty-one specimens were added to the Mineral Division reference collection, 98 of them from within the State. Locations of origin of the remaining 23 samples were Tasmania (2), Mexico (6), United States (5), Chile (3), Canada (3) and Germany (4).

A particularly striking sample of the basic magnesium chromium carbonate, stichtite, came from the Strahan area on the west coast of Tasmania.

Of the American specimens, five represented the first of their species to be added to the collection. These were the basic copper arsenate, clinoclase, the basic copper phosphate, cornetite, the zinc sulphide, wurtzite, the basic carbonate, callaghanite, and the complex silicate, levyne.

Other overseas acquisitions included outstanding specimens of dioptase, sulphur, vesuvianite, wulfenite and amethyst.

A selection from the minerals added from localities within Western Australia includes baryte, (from Howatharra and Argyle Downs), fluorite (Mt. Phillips, Cookes Creek, Yinnietharra), humtite (Burtville), beaverite (Northampton), rutile (Wongamine, Eenuin, Byro), euxenite (Dalgaranga), tapiolite (Tabba Tabba, Ravensthorpe), tantalite (Tantalite Hill, Mt. Edon), wolframite (Payne's Find), paratacamite (Warburton Mission, Kambalda), chrysocolla (Mullewa), brochantite (Wodgina), turquoise (Edmund), nickeloan-magnesite and gaspeite (Norseman, Canegrass, Kambalda), pentlandite (Ferndale), pyromorphite (Mons Cupri), lithiophorite (Broad Arrow), topaz (Denmark, Payne's Find), crocoite (Westonia), sapphirine (Quairading, Dangin), jarosite (Salmon Gums, Ashburton), hidalgoite (Wyloo), powellite (Youanmi), sphalerite (Kununurra), berlinite (Belele), heulandite (Kookynie) and molybdenite (Marvel Loch).

About a dozen standard sets of W.A. minerals were distributed to prospectors and educational authorities. These sets comprise 25 of the more significant minerals occurring in the State and provide a useful guide to prospectors and teachers.

A number of requests for specimens had to be refused due to lack of supplies and in keeping with the policy that, in these circumstances, preference is given to prospectors, scientific and teaching organisations. Requests from West Germany, New Zealand and the Eastern States were among those rejected.

Specimens of gaspeite and nickeloan magnesite were presented to the National Museum of Victoria and a collection of 32 specimens was sent to Professor T. S. West of Imperial College of Science and Technology, London. Specimens of W.A. basalt were made available on request to the University of Sydney, Department of Geology.

Analysed samples of limestone, gypsum, iron, manganese, lead and chromium ores were supplied to W.A. Institute of Technology for class purposes.

Building Materials

1. Aggregates.—A number of coarse aggregates were tested by accelerated chemical means for potential reactivity towards the alkali of cement.

These aggregates ranged from granites to basic rocks and river pebbles but only one showed deleterious reactions. This was a granitic gneiss from the Bullfinch area which was composed of feldspars, quartz and biotite mica in fragments ranging from fresh to strongly weathered.

Among the innocuous aggregates was one composed of fine-grained actinolite with feldspar, minor amounts of chlorite and grains of iron and titanium oxides.

River pebbles from Brickhouse Landing on the Gascoyne River gave borderline figures. Though composed mainly of quartz this sample also contained magnetite, ironstone pebbles, clay minerals and small amounts of microcline and silicious claystone.

Two sands were received from an industrial concern, one of which gave a satisfactory concrete whereas use of the second gave a concrete showing dark brown stains. The samples were mineralogically similar and neither showed an excessive amount of discrete organic particles. The unsatisfactory material however contained loosely bound sand aggregates not present in the satisfactory sand. The aggregates gave a very strong reaction for organic matter, much stronger than the separate grains from the same sample. It was concluded that the binding material of these loose aggregates was the major source of the staining.

2. Stains and efflorescences.—Water soluble and total vanadium were determined on a brick and on the clay from which it was fired. In both the fired and unfired product the ratio of total vanadium to soluble vanadium was considerably in excess of 10 : 1. The temperature of burning of the brick was 1,200° C.

A brick fired to a maximum temperature of 1,180° C showed bad vanadium staining. It was made from a mixture of two clays, a cream and a red. The vanadium content of the two clays was 70 ppm and 300 ppm respectively, with corresponding sulphur figures of 1,300 ppm and 900 ppm. Sulphur is recognised as a potential cause of the acid conditions favourable to the formation of coloured vanadium stains.

A sample of exudate from the underside of concrete slabs in a recently erected building was submitted by the Public Works Department. It was composed mainly of calcite with a stalactitic structure and resulted from carbonation of lime-bearing solutions from the cement.

An efflorescence appearing on a gypsum partition block wall was found to be hydrated sodium carbonate. The wall rested on a concrete raft with no damp-proof course between and it was assumed that the efflorescence was the result of atmospheric carbonation of alkalies migrating from the cement used in the concrete raft.

The presence of gypsum as a deposit on the internal face of cavity bricks in a hospital building was established but no convincing explanation could be found regarding its origin.

Four samples of exterior wall treatment taken in connection with legal enquiries were examined to establish their identity.

Dusts

Dust samples taken near the primary jaw crusher at the Horseshoe Manganese mine were found to contain about 7 per cent. manganese by weight, the concentration of manganese per cubic metre of air ranging from 60 to 240 milligrams.

Another dust presenting a potential health hazard originated from a zinc oxide salvage plant. Analysis showed the dust to consist mostly of zinc compounds with 0.17 per cent. lead and 0.005 per cent. cadmium.

Dusts submitted by Metropolitan Water Supply taken from a blasting pit were composed mainly of calcite but with a little quartz.

As part of a silicosis investigation, the Public Health Department submitted refractory bricks samples for determination of free silica.

Advice was given that with normal dust precautions there would be no risk of inhaling toxic quantities of cyanide when re-working old gold residue dumps.

The greatest number of dust samples was submitted by Public Works Department in continuation of their investigation of dust problems associated with the shipping of iron and manganese ores from Port Hedland. Determinations were made of the nature of the minerals in the samples and quantitative figures obtained for iron, manganese and hematite contents.

Five Departmental samples, taken from gauges in five metropolitan areas, were examined each month to determine the nature and size of the dust particles.

Minerals and Ores

1. Copper.—Many copper analyses were in connection with an investigation into the possibilities of heap leaching of oxidised copper ores with dilute sulphuric acid.

Preliminary bench scale work on copper extraction at various sizings and acid strengths led to a number of determinations of total copper and non-sulphide copper. Subsequent semi-pilot plant work was carried out at the Engineering Chemistry Division and the required analyses conducted in the Mineral Division.

Products were also analysed for a commercial enterprise engaged in the recovery of copper sulphate from scrap copper.

The usual wide range of copper-bearing samples was submitted for identification and analysis. A random selection includes a carbonaceous shale with large pockets of chalcopyrite; a siltstone with veinlets of malachite; a quartz brochantite rock assaying 23 per cent. copper; a rock from Kambalda carrying an appreciable percentage of paratacamite; malachite containing fine black unidentified inclusions and fringed with chrysocolla; an ore from Marble Bar assaying 21 per cent. copper containing malachite, chrysocolla, covellite, chalcocite and digenite and low-grade ore from Day Dawn in which the main copper mineral was atacamite.

2. Gold and Silver.—Gold and silver determinations were carried out for the Geological Survey Branch on suites of geochemical samples. The only other Government Department concerned with gold assays, namely State Batteries, submitted 95 samples of battery tailings during the year, 12 of which were umpire assays.

A number of batches were accepted from private companies who preferred the greater accuracy of the fire assays for gold and silver as compared with atomic absorption determinations. Though a number of public analysts are available for atomic absorption work, none is yet equipped to carry out fire assays. The largest batch, of 54 samples, was assayed for both gold and silver and an assessment made of the radioactivity of individual samples by radiometric counting.

Very little has been done towards the adoption of atomic absorption methods for gold determination but some preliminary work on the determination of silver by both atomic absorption and atomic fluorescence has shown encouraging results.

Silver assays were requested usually on galena concentrates or lead-bearing ores. The lead silver ratios varied over a very wide range, from 2 oz. silver per ton of galena from Lansdowne Station in the Kimberleys, 6 oz. from Nyang Station (Ashburton), 24 oz. from Chichester Range (West Pilbara), 60 oz. from Ashburton Station (Ashburton) and from 240 to over 1,000 oz. from a deposit on the Ivanhoe Station (East Kimberley). It is apparent that from the last two localities at least the silver must occur as a discrete silver mineral, not necessarily in intimate association with the galena.

Silver halide minerals were identified in a mine at Marvel Loch. From a head sample assaying about 23 dwt. gold and 94 dwt. silver per ton it was found possible to recover almost 90 per cent. of each in bench scale cyanidation tests at a cyanide consumption of a little over 2 lb. per ton.

A few samples were submitted for platinum assay but no platinum detectable by fire assay techniques was recorded.

3. Heavy Mineral Sands—The heavy mineral sands examined were largely prospected as a source of ilmenite and by products, though others were possible iron ore sands or alluvial tin ores.

Of 28 sands submitted as a source of ilmenite 20 were in reasonably accessible coastal deposits and the remainder were from inland areas.

As in other years it was not possible to draw conclusions as regards the value of deposits without extended sampling programs. With some submitted samples it was not clear whether the samples represented natural sands or concentrates.

A sand from Kununurra contained 54 per cent. ilmenite, 36 per cent. magnetite and 4 per cent. zircon. At Paynes Find ilmenite was approximately 40 per cent. and magnetite 15 per cent. while 25 miles north a similar sand also carried minor hematite and goethite.

A new inland area 20 m E of Morawa carried 60 per cent. ilmenite, 3 per cent. magnetite, 2 per cent. leucoxene and 2 per cent. zircon. A sample largely ilmenite with goethite and leucoxene and minor magnetite and zircon came from 42 miles from Perth towards Toodyay. Half a mile east of Yarloop, sands contained approximately 3 per cent. magnetite, 5 per cent. ilmenite with zircon and other iron oxides. A sand from 1½ m N of Pinjarra contained 2 per cent. of leucoxene and ilmenite with other iron oxides.

These latter samples represent an extension of interest in the Mandurah area. From Peel Inlet a sample contained 75 per cent. ilmenite, 4 per cent. magnetite and 3 per cent. zircon and from Mandurah ilmenite 55 per cent., zircon 9 per cent., magnetite 5 per cent. and trace monazite and rutile. From 2 m E of Mandurah samples averaged around 2 per cent. ilmenite with less leucoxene and iron oxides.

North of Perth, samples came from 5 m SW of Ledge Point, largely ilmenite and zircon with minor leucoxene and magnetite; from the mouth of the Moore River a heavy mineral fraction contained 55 per cent. ilmenite and 18 per cent. zircon; from Chapman River, ilmenite 56 per cent., garnet 34 per cent., zircon 4 per cent. and magnetite 2 per cent.; from Horrock's Beach area 60 per cent. heavy minerals largely garnet, with ilmenite and minor zircon and rutile; from 35 m south of Onslow, ilmenite 35 per cent., magnetite 30 per cent. with other iron oxides.

In the south, from Dunsborough samples averaged approximately 2 per cent. ilmenite and leucoxene; from Jasper Lake, ilmenite 32 per cent., magnetite 5 per cent. and zircon 2 per cent.; from Denmark, ilmenite 20 per cent, zircon 15 per cent., leucoxene 7 per cent. and monazite 5 per cent.; from Flinders Bay the heavy fraction was largely silicates with 3 per cent. ilmenite; from the Gairdner River estuary, ilmenite 53 per cent., zircon 24 per cent., garnet 8 per cent., leucoxene 5 per cent., and magnetite 3 per cent., from the Salt River, a sand with 93 per cent. heavy minerals contained 64 per cent. ilmenite, 12 per cent. magnetite and 7 per cent. zircon.

Work reported in the Annual Report of 1967, on magnetic sands from a coastal deposit, was extended in 1968 to beneficiation attempts, and examination of mineral types in the impurities. The material was not amenable to beneficiation.

Of the samples examined at public expense those submitted from inland localities include sand from Fields Find with approximately 60 per cent. heavy minerals made up of 3-5 per cent. magnetite and 55 per cent. other iron oxides. A sand from 100 ft. down a bore 7 m S of Kukerin was mainly magnetite with some quartz and 10 per cent. ilmenite. From Swan loc. 2185 a sand carried magnetite equivalent to 0.5 per cent. A black sand from 20 m. N.E. of Muntagin was 90 per cent. hornblende with magnetite and some ilmenite. From 4 m. S. of Donelly Mill a sand with 45 per cent. ilmenite also carried 15 per cent. magnetite and 20 per cent. other iron oxides together with approximately 5 per cent. zircon. Coastal deposits include a sand with 55 per cent. ilmenite from Lort R., 50 m. W. of Esperance, which carried 35 per cent. magnetite and 2 per cent. zircon, and from Urala Creek, Onslow, a sand with approximately 35 per cent. magnetite, 30 per cent. hematite and 15 per cent. ilmenite.

Cassiterite was the main interest in eight sands received from the south west. None was detected in a sample from Balingup nor in five samples from Greenbushes area which had heavy mineral concentrates ranging from 0.1 to 3 per cent. The heavy minerals were mainly magnetite, ilmenite and leucoxene.

Two samples from 3 m. E. of Greenbushes contained respectively 17 and 32 per cent. cassiterite. Other heavy mineral percentages present were ilmenite 73 and 44, magnetite 4 and 7, and one sample contained 3 per cent. tapiolite, 2 per cent. monazite, and 1 per cent. zircon.

An investigation was made to evaluate a dry separation process for heavy sands, devised by a client. The equipment consisted of a power driven dry blower. The product material was not a commercial concentrate and did not show significant upgrading.

One imported sample proved to consist of ilmenite, magnetite, quartz and feldspar. During the examination the sample was still in quarantine so that all parts separated in the identification had to be suitably treated.

During the year our records were called on on many occasions for details of occurrences and analyses of typical heavy sand material.

4. Iron.—Though a great many specimens submitted consisted of iron ore minerals in one form or another, no detailed analyses or mineralogical investigations were carried out.

Work in this area therefore consisted mainly of identification and iron determinations as a guide to grade.

5. Lead.—Assays were mostly on concentrates and other products from gravity concentration of lead ores. In addition to lead, many samples were assayed for copper, zinc, antimony, gold and silver.

An umpire assay for lead in commercial manganese ore showed a figure of the order of 0.1 per cent.

Galena from the Northampton area was coated with a powdery mineral of the jarosite group.

Samples of a very complex ore were received through the State Mining Engineer from PA 35 on Wyloo Station. They consisted essentially of galena with anglesite, cerussite, bindheimite and linarite as alteration products. Polished mounts showed the presence also of the rare minerals freiburgite, famatinite, bournonite and possibly the silver sulpho-salt proustite. The silver content ranged from about 4 to 8 ounces per ton. The material compares both in nature and complexity with the lead ore from MC 38 near Kununurra.

Another lead ore from the Ashburton area was mainly anglesite but with small associated amounts of the lead chloro-arsenate mineral mimetite. The first W.A. occurrence of hidalgoite (lead aluminium arsenate-sulphate) was also recorded from the same area associated with anglesite as the main lead mineral.

Further samples of perite (see Anuual Report, 1964) were received from near Glenflorrie homestead. The lead bismuth oxychloride mineral occurred as patches in a quartz carrying also cerussite containing a little relic galena.

6. Manganese.—Detailed analyses were mainly on commercial parcels of ore. One sample of high grade ore, assaying over 53 per cent. manganese, was analysed for trace elements to meet the requirements of potential buyers. Elements determined were calcium magnesium nickel, cobalt, tellurium, selenium, germanium, fluorine, chlorine, cadmium and phosphorus as well as manganese and iron.

Phosphorus, silica, aluminium, copper, zinc, barium and lead were required on other parcels.

A range of manganese minerals was received.

Pyrolusite from 30 miles S.E. of Kununurra carried thin bands of unidentified hydrous manganese oxides; a sample from 5 miles east of Payne's Find showed only insignificant traces of nickel and cobalt.

Cryptomelane from the Chichester Range assayed 50 per cent. manganese and was composed of unusually coarse very well crystallised rosetted needles. A lower grade cryptomelanegoethite sample from the same Range had potential as a ferruginous manganese ore.

Other localities from which cryptomelane was received included Warriedar, Bremer Bay, and the Wiluna area. A mixture of cryptomelane and lithiophorite from 40 miles north of Wiluna assayed over 50 per cent. manganese.

Lithiophorite predominated in another mixture with cryptomelane from Broad Arrow; the sample carried 0.18 per cent. nickel.

Psilomelane was the major manganese mineral in a sample from the south Kimberleys which assayed 45 per cent. manganese.

Braunite nodules from Balfour Downs were submitted (and because of their deceptive appearance, will no doubt continue to be submitted) as suspected tektites. They assayed about 43 per cent. manganese.

7. Nickel.—Apart from the 673 samples mentioned under "Geochemical" from the Rocky Dam Ministerial Reserve, of which 579 contained less than 0.01 per cent, nickel and the remainder between 0.01 and 0.1, a total of 980 nickel estimations were made. Of this number 565 contained less than 0.01 per cent. nickel, 299 contained between 0.01 and 0.1 and 116 contained amounts greater than 0.1 per cent.

Among the higher values recorded were 0.40 per cent. from 40 m S.E. of Meekatharra and 15 m N of Mangaroon homestead; 0.41 per cent. from 32 m south of Mount Magnet; 0.45 per cent. in opaline material from Miling; 0.46 per cent. from 35 m S.W. of Mount Newman and 8 m N.E. of Coodardy homestead; 0.47 and 0.57 per cent. from Kirkalocka station; 0.84 per cent. in prase from Mount Monger; 0.97 per cent. in chrysoprase from the Kennedy ranges; 1.05 per cent. from 15 m N of Mangaroon homestead; 1.28 per cent. in a nickeloan magnesite from 60 m E of Leonora; 2.95 per cent. in a nickeloan magnesite from 47 m N of Kalgoorlie; and 27.3 per cent. in a nickeloan magnesite from 16 m W.N.W. of Norseman.

Three samples reported from widely differing localities had all the mineralogical attributes of deep Kambalda ore. These assayed 7.08 per cent. (from 10 m S.E. of Wurarga), 7.80 per cent. (from 15 m N of Broome) and 8.65 per cent. (from 45 m N.E. of Broad Arrow).

A number of samples presented were from owners of farming properties concerned over pegging in neighbouring areas.

The determinations made were done largely by atomic absorption spectroscopy though some were assayed by the dimethylglyoxime gravimetric method.

8. Silica sands.—Apart from sands required as fine aggregate for concrete (q.v.), most samples submitted were potential glass sands.

The current issue of the appropriate ASTM specification (ASTM C146-68) has deleted the short alternative method for the determination of silica in glass sands, namely—

SiO_2 % = 100—ignition loss % — nonvolatile residue %

The much more time consuming conventional method, as now specified, has been used for all samples examined during the year.

Determinations on these sands include silica, iron, aluminium, titanium, ignition loss and sizing.

One sample contained about 0.9 per cent. of heavy minerals, made up mainly of leucoxene, ilmenite and zircon with traces of kyanite and rutile. The sample therefore contained excessive concentrations of iron and titanium but, as in some similar samples examined in the past, it was found that these impurities were on the whole of smaller grain than the quartz. Simple screening would therefore considerably improve the grade of the sand, as, alternatively, would electromagnetic separation.

A sample from Balikpapan, Indonesia was examined at the request of Department of Industrial Development. Results were SiO_2 99.5 per cent., Fe_2O_3 0.076 per cent., loss on ignition 0.25 per cent.

9. Tantalum-Niobium.—As in the case of tin, most analytical work was carried out on commercial sales parcels. Determinations required on such parcels included tantalum, niobium, tin, manganese and titanium.

Many prospector samples containing columbite-tantalite were graded by specific gravity determinations while chemical analyses were made on various magnetic and non-magnetic fractions obtained from up-grading processes.

Semi-quantitative mineral analyses were carried out by heavy liquid and electromagnetic techniques, and the tantalite fractions graded by gravity.

A number of samples were not amenable to grading by gravity due to the presence of tantalum and niobium minerals other than columbite-tantalite. One sample contained an appreciable proportion of fergusonite, tanteuxenite and yttrotantalite.

A number of tantalum and niobium analyses were made to provide standards for calibrating commercial X-ray fluorescence units.

10. Tin.—The majority of the tin analyses carried out were on sales parcels of cassiterite concentrates.

Various products were examined for State Batteries in connection with preliminary runs of the new electromagnetic separation plant at Marble Bar. Products examined included cassiterite concentrates, columbite-tantalite middlings and concentrates and mixtures containing garnet, ilmenite, iron oxides and silicate gangue minerals. Parcels treated had originated mainly from the Pilbara but examinations were also made of fractions from Greenbushes ore.

Examination of a clay-quartz rock from Poona showed it to carry 3 per cent. of cassiterite which could be freed and concentrated by crushing to 10 mesh.

Nine samples of tin-bearing rock were assayed at the request of a commercial firm for use as standards in their own laboratory. Tin contents ranged from 0.033 to 0.112 per cent.

Specimens of translucent cassiterite were received from Mount Francisco.

11. Titanium. — Sand containing titanium-bearing minerals are dealt with under Heavy Sands.

Specimens of massive ilmenite were received from a number of localities including Payne's Find, Canning Hill, Williams, Arthur River Station and the Marble Bar area. The sample from Arthur River was a manganese-bearing variety.

Rutile samples were submitted from Wangamine. Large crystals of rutile with a little intergrown ilmenite were received from Byro station and a niobium-bearing rutile associated with a little columbite came from the vicinity of Eenuin.

Most chemical work in the field of titanium ores and products was carried out for Engineering Chemistry Division in connection with a research program on the up-grading of ilmenite.

Determinations made at the request of producers of heavy sand concentrates included titanium and phosphorus on various grades of leucoxene, which were further examined mineralogically to determine the percentages of zircon, quartz and kyanite, present.

Samples of ilmenite representing commercial products were submitted for umpire assays for titanium and ferrous iron, while one sample was subjected to complete analysis involving the determination of twenty-five elements.

A batch of eight heavy mineral concentrates was examined by magnetic fractionation as a guide to up-grading procedures. Monomineralic fractions could not be obtained owing to variations in magnetic susceptibility due to weathering and compositional differences but the major portion of the ilmenite reported in the 0.0 to 0.30 amp fraction which also carried some garnet, iron oxides and silicates. The fraction contained 54 to 56 per cent. titanium dioxide.

Miscellaneous Investigations

1. Metals and alloys.—An analysis was made of the metal used in casting the Pipes of a public statue of Peter Pan. This was requested by the Perth City Council as an aid to repair and restoration.

A non-ferrous alloy submitted by the Royal Australian Navy was analysed to determine whether or not repairs to damaged equipment on a naval vessel could be effected by welding.

The Main Roads Department submitted nine samples of steel wire for analysis. Figures were required for carbon, silicon, sulphur, manganese and phosphorus to check compliance with specifications.

The surface coating of an ancient coin was examined for the Western Australian Museum as an aid to the coins classification.

A number of white metal scrap alloys were analysed for tin, lead, antimony and copper.

2. Corrosion.—A corrosion product from a heat exchanger of an industrial plant in the North West was found to have a chloride to sulphate ratio typical of sea water, i.e., about 7:1; the predominating metal was iron, over 10 per cent. of which was in the ferrous state indicating a still active corrosion condition.

A P.M.G. cable box, constructed from plastic, aluminium and brass was submitted for identification of corrosion products. A blue-green copper product was found to be copper formate, a greenish product was largely hydrated zinc formate while a grey product associated with the aluminium gave an X-ray diffraction pattern matching that of synthesised aluminium formate. The box, when originally opened, had been full of black ants, all dead.

Scrapings from a non-ferrous mortar received from the Gilt Dragon wreck were examined at the request of the W.A. Museum. Cuprous oxide was the major component with atacamite, calcite and unidentified compounds also present.

The white corrosion product on the soleplate of a steam iron was found to be halotrichite, a hydrated iron aluminium sulphate. A possible cause of corrosion could have been the use of distilled water slightly contaminated with battery acid.

A deposit in hydraulic fluid from a drilling rig was mainly mill scale with minor amounts of mineral particles, iron and other metal fragments and coloured paint flakes.

An engine oil was found to be contaminated with iron shavings, corundum and a little carborundum.

Samples of corrugated galvanised iron were examined at the request of State Housing Commission. The material had suffered corrosion either during transport or while stored on building sites in the North West. Thickness measurements were made of both the base metal and the zinc coating and the weight of zinc per square foot determined. These were, with a single minor exception, in keeping with specification requirements. Both black and white stainings were evident on the protective coating and were the types most likely to result from storage of new sheets of galvanised iron in hot humid wet conditions.

The surfaces of three samples of galvanised wire were examined to ascertain if any film was produced by cooling (following galvanising) in bore water as opposed to scheme water. No surface coating that could have been derived from cooling water was present.

3. Artificial minerals.—Spurious minerals received included a translucent light green specimen thought to be obsidian but which proved to be an artificial glass, a slag containing small flakes of metallic copper, and a metallurgical product containing appreciable percentages of copper, antimony, nickel, and arsenic with an ounce of silver and four ounces of gold per ton.

Heavy greyish white metallic particles obtained by panning exploration samples from the North West were found to be tungsten carbide, presumably derived from drill bits.

4. Selected mineral examinations.—In September the Geological Survey Branch submitted 17 mineral concentrates prepared from specimens of the gabbro bodies forming the Bell Rock, Blackstone, and Jameson Ranges in the Giles Complex, Blackstone Region astride the W.A.-S.A. boundary.

The Giles Complex 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 over an area of 7,500-8,000 square miles.

The Complex has been subdivided into four major, physically unconnected, sheet-form bodies. These have been named, in order of increasing structural depth—

Jameson Range Gabbro
Blackstone Range Gabbro
Hinckley Range Gabbro
Michael Hills Gabbro.

The Survey is studying differentiation and variation within the rock masses, particularly the important iron/magnesium ratio in both bulk rock composition and in pure samples of the iron magnesium mineral series olivine $(Fe, Mg)_2 SiO_4$, hypersthene $(Fe, Mg) SiO_3$ and augite $(Ca, Fe^{++}, Mg, Fe^{+++}, Ti, Al)_2 [(SiAl)_2O_6]$.

The concentrates submitted consisted of 11 olivines, 3 hypersthenes and 3 augites for final purification, complete analysis and measurement of absolute density, optical properties and unit cell dimensions by X-ray diffraction.

The detailed results are to be correlated to determine the best single diagnostic property for rapid determination of Fe/Mg in numerous specimens in any future intensive study of the area. All the properties for study show linear variation with composition.

The final purification was done by a combination of magnetic separation with a Frantz Isodynamic separator and heavy liquid centrifuge separation using methylene iodide and Clerici solution.

Absolute density measurements were performed using 10 ml capacity silica pycnometers and calculations based on standard tables of absolute water density.

The particular optical properties of use in this variation study are the three refractive indices $\alpha\ \beta\ \gamma$ and the optic axial angle $2\ V\ \gamma$. The refractive indices were determined on small grain samples by complete immersion in methylene iodide-sulphur-alpha bromonaphthalene mixtures in a special cell.

The $2\ V\ \gamma$ measurements were made on thin rock sections with a Cooke universal stage. All optical measurements were made in sodium light.

So far the optical data, density and chemical analyses correlate well.

The X-ray work will be done in two stages. Initially a refined measurement of the 1.3.0 line will be made on powder X-ray diffraction patterns of the 11 olivines. Previous workers have shown a sensitive linear variation of the 1.3.0 spacing between those of the two end members, Fe_2SiO_4 and Mg_2SiO_4 of the olivine series. Finally the refined unit cell dimensions will be determined using a Weissenberg single crystal camera and computing methods on all 17 samples.

Two products from a commercial plant were each divided into seven fractions with an isodynamic electromagnetic separator and the quantitative distribution of the individual minerals determined. The minerals concerned were ilmenite, leucoxene, xenotime, monazite, zircon, garnet, staurolite and spinel. The appropriate fractions were analysed to determine their content of yttrium-group rare earths.

A number of samples representing shipment parcels of monazite were submitted during the year, determinations required in each case being thorium dioxide, rare earth oxides and acid insoluble material.

A sample of Cookes Creek fluorite was added to the mineral collection as being reasonably typical of the kind of concentrate that could be readily obtained from this deposit. Analysis gave the following figures:—

	per cent.
Total calcium fluoride, CaF_2	78.2
Silica, SiO_2	12.6
Effective calcium fluoride, CaF_2	50.0
Barium sulphate, $BaSO_4$	6.3
Lead, Pb	0.63
Sulphur, S, as sulphide	0.18

It is evident that more sophisticated treatment than readily available at the site would be necessary to produce a commercial grade product, though perhaps small parcels could be recovered by careful handpicking.

Acid grade fluorite must contain less than 1.5 per cent. silica and ceramic grade very little more. For metallurgical purposes at least 55 per cent. (but preferably 60 per cent.) effective calcium fluoride is specified.

5. Geochemical samples.—Early in the year a report was issued on a further batch of 146 rock samples from the Kalgoorlie area which had been assayed for arsenic. This was part of a programme of establishing the relationship of gold ore bodies with arsenic haloes.

Subsequently this investigation was extended to include antimony estimations. It was obvious that Atomic Absorption Spectroscopy could not produce the sensitivity necessary to show anomalous fluctuations in concentration which are of interest. An alternative colourimetric method which promised the required sensitivity was shown to suffer interference from gold. A satisfactory method was finally devised and estimations were made on 476 rock samples.

A large number of samples received from the Geological Survey Branch were prospecting samples in the sense that the elements of interest were present in non commercial trace amounts. A number of these from Laidlaw Range, Bugle Gap, Mount Pierre, Melita Station, Mount Palgrave, Cue, Eastmans Bore, Coonan, Northampton, Warburton Range, Walkaway and Noraling were received in batches, the size of which did not justify "mass production" techniques. They represented granites, oxides and carbonates of copper, manganese, and calcium, gossanous iron ore, jaspilites and soils. The elements estimated were copper, nickel, zinc, lead, silver, cobalt, gold, iron, magnesium, chromium, manganese and vanadium. The latter six were required only on relatively few samples.

On a rock sample from Melita Station, the material filling vughs was examined separately but showed no concentration of any of the elements determined. In fact it contained less than other samples representing the rock mass.

Two batches of samples from the Rocky Dam Ministerial Reserve were in sufficient quantity for geochemical treatment. They comprised 577 soil and clay pan samples, 96 gossans and a dolomitic calcite.

Thirty-five samples of plagioclase separated from various levels of the rock mass of the Giles complex were analysed for Na_2O, K_2O, CaO and strontium. The relationship of strontium to other cations was not as expected from the literature references, but did differentiate distinct areas in the formation.

It has not been the policy of the Laboratories to accept from private sources numbers of samples amounting to a geochemical survey. Various private laboratories now operate in this field in Western Australia and such work has been directed to them.

6. Others.—A yellow crystalline sediment forming in wines was identified for the Department of Agriculture as acetylurea.

For the same Department, the inorganic fraction of a sample of pig faeces was found to be quartz with minor amounts of calcite and magnetite. The suspected presence of glass was not confirmed.

To obtain data which could lead to a better understanding of the mechanism of formation of urinary calculi, specimens of such calculi from 40 sheep were examined for the Animal Division of the Department of Agriculture. Information was sought on the composition of the nucleus and peripheral material and, where banding was evident, the composition of the bands. The main compounds identified were silica, calcite and weddellite (calcium oxalate dihydrate): one specimen contained aragonite associated with calcite, another was composed mainly of an unidentified organic compound. The series showed a wide range of composition and structure. Some consisted essentially of silica only, others of calcite only but most were more complex. One for example though composed mostly of calcite showed narrow zones of weddellite with a centre of amorphous silica. Another had a silica core with alternating weddellite and silica zones with the silica in general containing small spots and rosettes of weddellite. Photomicrographs were provided to illustrate the main types.

A human kidney stone was examined by X-ray diffraction and found to consist essentially of calcium oxalate as a mixture of the dihydrate (weddellite) and a monohydrate.

In a case of suspected theft being investigated by C.I.B. dust extracted from the base of corrugated cardboard cartons containing cigarettes was shown to have unusual components identical with those of sweepings from a garage in which the stolen goods were suspected to have been stored.

A sample of mud taken by C.I.B. from the scene of an explosion involving a safe-breaking attempt was compared with material from the finger nails of the suspect. The mineral assemblages were identical and the presence of similar types of diatom skeletons in each exhibit was established.

Fifteen samples of sprayed metal were examined to determine the weight of coating per square foot.

The coating was an iron phosphomolybdate and its density was estimated from the molybdenum content of the coatings.

A deposit from a metropolitan drain was examined for the Swan River Conservation Board. It was amorphous in character and no specific compounds could be identified by X-ray diffraction. Partial chemical analysis showed it to be composed of sulphates and phosphates of iron, aluminium and calcium with minor amounts of lead and zinc compounds.

Complete Analysis

Twelve complete analyses reported during the year completed work on a batch of 23 samples received the previous year. These samples represented type specimens of varieties of the main gold host rock of Kalgoorlie, namely the Golden Mile dolerite. The analyses were carried out for a mining company to provide data for an extensive project being undertaken by its research geologists aimed at defining more accurately the complex layered nature of this host rock.

Six of the complete analyses reported to Geological Survey Branch during 1968 were of rocks being studied in the course of an investigation to be published as a Bulletin covering the Blackstone Range area on the South Australian border. One of the rocks was a granophyre, the remainder were rhyolites.

Three other samples analysed for the Survey were two cherts and a shale from the Brockman Iron Formation. These samples were submitted in connection with the extensive study of the Hamersley crocidolite occurrence.

A sample of an unusual primary titanian hornblende, kaersutite, was isolated from its parent rock, a magnetite kaersutite pyroxenite, occurring at the south east end of the Jameson Range. A complete analysis, carried out at the request of the Geological Survey Branch, gave the following figures:—

	per cent.
SiO_2	40.78
Al_2O_3	12.46
Fe_2O_3	3.17
FeO	12.67
MgO	10.86
CaO	11.48
Na_2O	2.45
K_2O	0.59
H_2O^+	1.90
H_2O^-	0.45
CO_2	0.09
TiO_2	3.04
P_2O_5	0.04
S	less than 0.01
Cr_2O_3	less than 0.01
V_2O_5	0.23
NiO	0.03
MnO	0.11
F	0.03
Total	100.38
less $O^- =$	0.01
	100.37

Analyst: P. Hewson
Absolute density 3.276

Further work is in hand on this mineral to determine its cell dimensions, refractive indices and optic axial angle.

Other complete analyses were carried out at the request of a company producing heavy sand concentrates in the Capel area. Materials analysed were a standard commercial grade ilmenite and a sample representative of a leucoxene accumulation dump.

Mineral Identifications

The most common sulphide submitted for identification was, predictably, pyrite.

Irregular nodules of pyrite from 16 miles south east of Busselton showed the yellow-green alteration product melanterite; in some nodules the pyrite had obviously replaced wood.

The mineral was received as concretions in carbonaceous shale and chert from near the 130 mile peg on the Mount Newman railway and, in the same form, from Roy Hill and inland from Quinns Rock where its occurrence was typical of that associated with reducing conditions in a swampy environment.

Other localities included Coal Mine beach near Walpole and, associated with vein quartz, from Collie and the eastern end of the Stirling Ranges.

A specimen from Donnelly River mill was a gneiss with pyrite bands of pyrrhotite and traces of chalcopyrite.

Any samples containing pyrrhotite were assayed for nickel as a routine procedure. A sample of basic rock from near Ferndale, in which pyrrhotite was the predominant sulphide with lesser amounts of chalcopyrite and traces of pentlandite assayed only 0.16 per cent. nickel. A specimen from Ninghan Station in which pyrrhotite was associated with goethite and quartz assayed 0.14 per cent. nickel.

Other pyrrhotite containing specimens, which showed only insignificant traces of nickel came from Payne's Find and Mount Magnet. A metamorphic rock from the vicinity of Canning Hill contained lenses of pyrrhotite and chalcopyrite with traces of sphalerite but showed only 0.01 per cent. nickel.

A range of copper sulphide minerals were identified and have been referred to under Copper.

Fragments of pegmatite from 10 miles south of Southern Cross contained arsenopyrite. This sulphide was more plentiful in material from Wodgina in which the arsenopyrite was associated with quartz and fuchsite mica. A sample from Warriedar contained much arsenopyrite, together wth magnetite, goethite, pyrite, marcasite and scorodite, the latter as an alteration product of the arsenic sulphide mineral. The arsenic-bearing material from Wodgina carried about 4 dwt. gold per ton but that from Warriedar assayed 50 dwt.

An interesting spinel was received from twenty miles north of Mundiwindi. Classified as picotite it showed an iron (Fe) content of 14.1 per cent. with chromium (Cr) 27.5 per cent.

A striking specimen of magnetite came from ten miles east of Ravensthorpe. The magnetite had replaced a prismatic mineral, possibly hornblende.

A number of specimens of common opal was received, some of which were of a quality to interest lapidarists.

The combined water content of a fragment of precious opal from Coolgardie was determined at 6.4 per cent. A common opal from Koonmarra Station consisted of fine crystals of tremolite in an opal matrix. A green opal from Mount Kenneth owed its colour to inclusions of fine green mica. A specimen from about 25 miles south east of Ongerup consisted of common opal developed from the alteration of the spongolite rock typical of that region; it contained minor quantities of quartz and numerous minute flakes of graphite.

Chrysoprase from the Kennedy Range was of good quality as were chosen fragments from material from Mount Monger. The Mount Monger chrysoprase contained 0.84 per cent. nickel, that from the Kennedy Range assayed 0.97 per cent. nickel.

Fluorite specimens were received from Yinnietharra, Nanutarra, Mount Philip and Kununurra.

An interesting carbonate mineral from the Laverton area was the first of its species recorded in W.A. This mineral, huntite, is an orthorhombic magnesium calcium carbonate first discovered in 1953 as a white powder in vughs in a magnesite deposit in Nevada. In W.A. its occurrence was also associated with magnesite in severely weathered and altered ultrabasic rock. The most commonly received sulphate mineral was gypsum, twenty-one samples being submitted during the year. As well as mineral identification work, chemical analysis was carried out on many of them for grade assessment.

Four of the baryte specimens identified originated from the Kimberley Division. None would have met requirements for use as a pigment or extender in paints, due mainly to discoloration, but most would have been satisfactory for use as drilling mud.

Brochantite occurred as an alteration product of chalcopyrite in a calcite matrix from 25 miles south east of Turkey Creek and as the main copper mineral in a sample assaying 23 per cent. copper from 4 miles S.W. of Wodgina.

A white efflorescence occurring on the soil surface of certain areas on Twin Peaks Station was identified as the sodium sulphate mineral thenardite.

A sample of bright yellow jarosite from the Salmon Gums area assayed 8.70 per cent. potash. A white sample from the same locality contained about 40 per cent. alunite, the remainder being fine quartz and clay minerals.

One of the most interesting of the phosphate minerals examined was turquoise. It originated from Wanna Station and was associated with alunite, black quartz and small amounts of another phosphate mineral, strengite. It represented the first W.A. occurrence of turquoise recorded at the Laboratories but unfortunately was not of gem quality.

Conichalcite, an arsenate of copper and calcium, was identified as an encrustation on goethitic ironstone from Glen Roebourne.

A specimen of the spectacular lead chromate mineral crocoite was sent in for identification from the well known occurrence at Westonia.

A concentrate from a mining group in the Pilbara was found to be a mixture mainly of tanteuxenite and cassiterite with an overall tantalum pentoxide content of 30 per cent.

A sample of euxenite from the Marble Bar area gave a radioactivity 500 times background.

Euxenite and wolframite, cassiterite and tantalite was received from Dalgaranga.

An analysis was made for tantalum, tin and titanium on a parcel originating from the Pilbara area. Predominant minerals were fergusonite, tanteuxenite, yttrotantalite, cassiterite and monazite.

Silicate minerals, as would be expected, made up the biggest group of unknowns submitted for identification. With the nickel boom at its peak and in view of the popular conception that links the colour green with indications of nickel, it is not surprising that an exceptional number of specimens of fuchsite, nontronite, and epidote was received.

Kyanite, with traces of staurolite, occurred as bands in a gneiss from the Hopetoun area, also in a schist with traces of tourmaline from the same area. Long slender crystals of kyanite in quartz came from Yarri and bladed crystals in schists from the well known Bindoon deposit.

An outstanding specimen of topaz was identified from Payne's Find.

Six samples of beryl, representing commercial parcels, were analysed and showed a BeO content ranging from 10.2 per cent. to 11.7 per cent. Specimen material from Payne's Find gave a figure of 12.1 per cent. beryl.

Only three samples submitted for mineral identification proved to contain beryl.

A sample of gossanous material from an undisclosed locality within the State contained a vitreous bright green mineral that proved to be the chromium garnet uvarovite.

A number of talc samples was received but none was of outstanding quality.

Heulandite, occurring as brown radiating needles on a joint plane in granite was identified from a mine dump at Kookynie.

A mica, suspected of being roscoelite, was found to contain no vanadium. It was identified as muscovite.

A black rock from 10 miles north of Quairading was a devitrified volcanic glass composed of microcrystalline feldspar traversed by numerous fine veins of chlorite. Its striking radial structure was probably due to strains imposed during solidification.

Prehnite was identified from Pindar and Mount Vernon and, as pale green rosettes, from Mount Hardman in the Kimberleys.

New Localities

The Annual Report for 1967 recorded the occurrence of antlerite, anglesite, cerussite and galena from a locality 13 miles north of Kununurra. This should have read 13 miles west of Kununurra.

Minerals for which new Western Australian localities were recorded in 1968 are listed below:—

Mineral	Locality
(a) Kimberley Division	
Sphalerite	13 m W of Kununurra.
(b) North West Division	
Bindheimite	Wyloo.
Bournonite	Wyloo.
Brochantite	4 m W of Wodgina.
Cryptomelane	7 m E of Ilgararie.
Famatinite	Wyloo.
Freiburgite	Wyloo.
Hidalgoite	Wyloo.
Jarosite	12 m SE of Ashburton Homestead.
Pyrolusite	7 m E of Ilgararie.
Stengite	20 m E of Wanna Homestead.
Turquoise	20 m E of Wanna Homestead.
(c) Murchison Division	
Chrysocolla	18 m N of Mullewa.
Euxenite	Dalgaranga.
Ilmenite	Canning Hill.
Malachite	18 m N of Mullewa.
Monazite	Melville.
Powellite	5 m N of Youanmi.
Rutile	1 m N of Byro Homestead.
Siderite	1 m NW of Cue.
(d) South West Division	
Glauconite	Sussex Loc. 2718.
Ilmenite	15 m NE Corrigin.
Molybdenite	6½ m S of Kukerin.
Pentlandite	4½ m S of Ferndale.
Topaz	Denmark.
(e) Central Division	
Cryptomelane	Sandstone.
Kyanite	2 m W of Yarri.
Lithiophorite	8 m SW of Broad Arrow.
Magnesite	Mount Jackson.
Paratacamite	Kambalda.
(f) Eucla Division	
Jarosite	18 m E of Salmon Gums.
(g) Eastern Division	
Paratacamite	near Warburton Mission.

DIVISION VIII

Annual Report of the Chief Inspector of Explosives for the Year 1968

The Under Secretary for Mines

This report on the administration of the Explosives and Dangerous Goods Act 1961-1967 and the work of the Explosives Branch for the year ending 31st December 1968 is submitted for the information of the Hon. Minister in accordance with Section 10 of the Act.

STAFF

Retirement

Chief Inspector of Explosives Mr. F. F. Allsop retired on 13th February 1968 after 20 years in the Explosives Branch and a total of 42 years with the Mines Department.

Appointments

Chief Inspector of Explosives. Mr. G. A. Greaves was appointed on 6th March 1968.

Inspector and Technical Officer. Mr. H. Douglas was appointed and transferred from the Government Chemical Laboratories. He commenced on 3rd January 1968.

Inspector of Explosives. Mr. C. A. Bryant was appointed and commenced on 7th October. Since his appointment Mr. Bryant has qualified by examination as a Member of the Institute of Fire Engineers.

Clerk/Typist. Miss E. Rengel commenced duty on 16th December 1968.

There were no resignations and no other change of staff during the year.

OFFICE ACCOMMODATION

The Explosives Branch was first installed in the two semi-basement rooms in Treasury Building in 1925 and continued to function there for 43 years until December 1968 when the offices were moved to new accommodation in Albert House, 10 Victoria Avenue Perth. The new offices provide greatly improved facilities for the expanding functions of the Branch. The office records of explosives licences have been transferred to a visual card index system which provides easily accessible information without reference to licence files. A general file system has been set up within the new office of the Branch which now handles its own files independently of the general Departmental filing system. The present accommodation is temporary and it is intended that the Branch will finally be accommodated with other Branches of the Mines Department in Mineral House which is now under construction.

LEGISLATION

No further amendment was made this year to the Explosives and Dangerous Goods Act 1961-1967.

The Flammable Liquids Regulations 1967 were again amended in Regulation No. 2 deferring the date of operation for another year until 1st November 1969.

The Explosives Regulations 1963 were re-drafted to remove the Sections dealing with shopgoods fireworks and to amend the regulations for conveyance of explosives on road vehicles. The amended regulations have not yet received final approval but will probably be gazetted next year. Both the Act and Regulations have been out of print for some time and it is proposed to issue a reprint of the consolidated Act with the Regulations as amended.

Assistance was given to the State Mining Engineer and the Senior Inspector of Mines with their task of re-drafting the Mines Regulations. Considerable time was spent on the sections dealing with storage and use of explosives in order to achieve consistency with the Explosives Regulations and with the "Explosives Code" as revised by the Standards Association in 1967.

Rules for storage of ammonium nitrate and the manufacture of ammonium nitrate/fuel oil blasting agent were revised and distributed in sheet form during the year. These rules have statutory force under Regulation No. 29 of the Explosives Regulations 1963.

The Explosives Regulations 1963 have been out of print for some time but a publication was prepared setting out all requirements of the regulations for conveyance of explosives on road vehicles. This is available for issue to transport firms who are tendering for conveyance of explosives by road in various parts of the State. There has been a steady demand for this information throughout the year.

AUTHORISATION OF EXPLOSIVES

The following new explosives were authorised by Orders in Council during the year:—

Class 2—Nitrate Mixture

M-Pak	600	(zz)
M-Pak	662	(zz)
Nobel Drimix		(zz)
Anforce		(zz)
Anpower		(zz)
Amex		(zz)
Econex		(zz)

Class 3—Nitro-Compound—Division 2

Tovex Regular	(zz)
Tovex A6	(zz)
Anzomex Boosters	(zz)

Class 6—Ammunition—Division 2

Aquaflex	(zz)
Geoflex	(zz)
Atlacord 50	(zz)
Nobel Boosters	(zz)
Anzomex Cutters	(z)

Approval was given for amendments made to the definitions of the following explosives which had previously been authorised:—

Class 2

Molanal	(zz)

Class 3—Division 1

Anzite	(zz)
Aquamex	(zz)

MANUFACTURE OF EXPLOSIVES

Three Licences to Manufacture Explosives were issued during the year. Two of the licences were for small scale manufacture of fireworks (Class 7 division 2) which are used for local displays; the third licence was for full scale production of slurry explosive in a factory near Port Hedland. This is the first time in Western Australia that a mining explosive has been blended and packaged in a licensed factory. The product is not a dynamite but a gelatinised mixture of ammonia nitrate, water and combustibles which is used for large scale open-cut mining. Another similar type of slurry explosive is also manufactured on a large scale at Mt. Tom Price but under conditions which allow the mixture to be classified as a blasting agent. In this case therefore, no factory licence is issued and production of slurry is covered by a Licence to Manufacture Blasting Agent.

Large quantities of ammonium nitrate/fuel oil (ANFO) mixture are now used for a wide variety of blasting work in Western Australia. ANFO is used in underground gold mines, in open-cut mines and quarries and also for land clearing and stump-blasting. This form of manufacture at the place of use is covered by the issue of a Licence to Manufacture Blasting Agent and 92 such licences were issued during the year.

IMPORTATION AND SUPPLY OF EXPLOSIVES

Supplies of explosives from the Australian factory in Melbourne were received in a total of seven shipments and eighty rail consignments throughout the year. It is now general procedure to ship supplies direct to Koolan Island, Port Hedland and Dampier with Woodman Point as the last port to call.

Three large shipments of mixed explosives cargo—ammonium nitrate, dynamite explosives and other items—in addition to eight shipments of ammonium nitrate were received from the U.S.A.

Ammonium nitrate supplies were further supplemented by fourteen shipments from Japan all of which were off-loaded at North West Ports. Kalgoorlie and eastern goldfields were supplied by rail transport from N.S.W. and Victoria.

Importation of Marine Seismic Explosives for oil survey work on the continental shelf continued and shipments were received from U.S.A. as well as a quantity from the U.K. the latter being surplus from similar operations in the North Sea area.

Explosives Imported During 1968

Gelatine nitro-compounds—1,594 short tons.
Marine seismic explosives—750 short tons.
Manufactured slurries—176 short tons.
Primers and boosters—99 short tons.
Blasting powder—2,050 lb.
Rifle powders—1,850 lb.
Whaling explosives—70 cases.
Detonating fuse—7,427 cases.
Detonators (plain)—233 cases.
Detonators (electric)—1,594 cases.

Ammonium Nitrate for Blasting

Total of all importation by ship and rail during 1968—17,804 short tons.

The quantity of ammonium nitrate used for blasting has increased four fold in the two years since 1966. Supplies came from U.S.A., Japan and the factory in New South Wales. In 1969, production will commence at the Kwinana factory in W.A. and prilled nitrate for blasting will then be available from within the State.

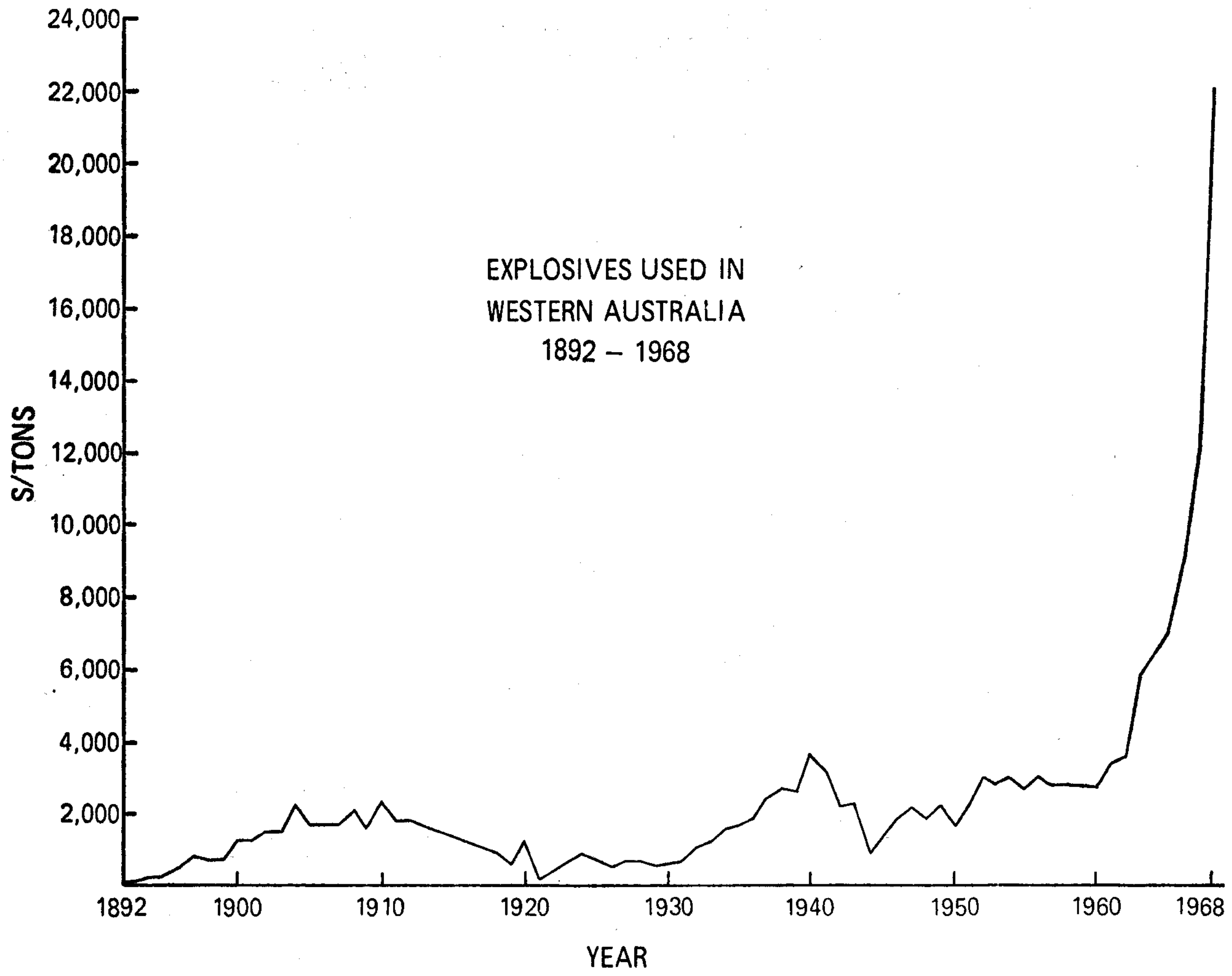
Manufacture of Slurry Explosives in W.A.

Production of slurry explosive commenced at a licensed factory located at Port Hedland and the product is distributed to open-cut mines in the district. At Mt. Tom Price a different type of slurry explosive is prepared in a plant erected on the mining lease but the final mixing takes place on a special vehicle at the boreholes. This operation is carried out under a Licence to Manufacture Blasting Agent.

Total of all slurry explosives manufactured during 1968—4,996 short tons.

Total Consumption of Explosives

In recent years there have been rapid developments in explosives technology with increasing use of ammonium nitrate in the form of blasting agents and slurry explosives. The conventional dynamites containing nitroglycerine are still widely used but the quantity is less than it was prior to 1960. In 1968 the importations of nitroglycerine explosives were little more than half of the general level in the period 1950 to 1960 but the quantity of boosters, fuses, detonators and other accessories remains high. Explosives used for both marine and land seismic surveys continue to be used in large amounts and these, added to the blasting agents and slurry explosives, produce a total of all explosives used which is unparallelled at any time in the history of Western Australia. The graph of annual importations since 1892 shows the phenomenal increase in the use of explosives in W.A. from 1962 onwards. Ammonium nitrate has been included since it is all used for blasting mixtures of various types but slurries are excluded from the data since they contain a large proportion of nitrate. The graph is for bulk explosives only and takes no account of the large quantities of fuse, boosters and detonators which are used as accessories in blasting operations.



LICENCES AND INSPECTION

Licences were issued in accordance with the Act and at 31st December 1968 the following licences were held for various purposes:—

Licences to Manufacture	3
Licences to Import	4
Licences to Manufacture Blasting Agent	92
Licences to Sell Explosives	56
Licensed Premises	41
Licenced Magazines	168
Licences to Convey Explosives	43

Five inspection trips were made to Port Hedland and other North-West centres, one to Geraldton, one to Kalgoorlie and one to Albany. Magazines and stores licensed to sell explosives were also inspected in country districts and throughout the Metropolitan Area. In many instances small quantities of explosives were found to be deteriorated and unfit for use. These were removed and destroyed. There were numerous breaches of the Act and Regulations but without knowledge or intention of committing an offence. In all instances corrective action met with willing co-operation from the licensees and no prosecution was made. Licences were cancelled for one store and one magazine because the owners were no longer able to comply with requirements owing to change of circumstances. One Licence to Import Explosives was suspended under Section 51 of the Act because the importer did not comply with requirements for storage of explosives. The licence was subsequently re-issued when conditions became satisfactory.

EXPLOSIVES RESERVES

Woodman Point.—A new magazine with capacity for 60 tons of explosives was constructed by Du Pont Far East Inc. in the general area occupied by their other buildings. Two public magazines formerly used for storing imported shopgoods fireworks are now stocked to capacity with conventional dynamite explosives for which weekly storage charges are made in accordance with the regulations. A small Government Magazine was constructed for the purpose of segregating and storing all sample material and other explosives which are intended for destruction. A chain saw was added to the general equipment for use in clearing and cutting of dead timber on the Reserve.

There have been no building developments in the vicinity of the Reserve this year and no further encroachment on the surroundings. No further proposal has been made for re-siting the magazines and there has been no action directed at moving this Explosives Reserve since the previous year.

Port Hedland.—The new Reserve on the Pippingarra Creek has two permanent large capacity magazines erected on it. An access roadway has been provided by the Department during this year.

Other Reserves.—At Carnarvon and Onslow the old original Reserves were surrendered to be used for other purposes and at each place a new and larger Reserve was vested in the Hon. Minister for Mines this year. Negotiations are proceeding for moving the Majimup Reserve to a more remote site and a small Reserve at Margaret River was surrendered for farm use. On the Geraldton Reserve a magazine has been erected by the Public Works Department for their own use.

EXPLOSIVES DESTROYED

At Port Hedland, 44 cases of explosives were found to have deteriorated as a result of improper handling and storage. They were destroyed by burning.

At Woodman Point, 119 cases of explosives were destroyed by burning after an inspection revealed that they were exuding free nitroglycerine. On another occasion 126 cases of explosives were dumped at sea after they were found to be exuding and unfit for distribution.

Throughout the year the Branch continued to accept small quantities of explosives from the Police Department and other sources. Together with unwanted sample material, these explosives were temporarily stored in the new sample magazine and destroyed by burning from time to time.

FIREWORKS

With full implementation of the Amendment Act of 1967, the Branch was this year relieved of the work associated with importation and inspection of shopgoods fireworks. No fireworks of the shopgoods class have been imported for the past two years and there are now no stocks held in Western Australia. The larger display pieces are manufactured by two pyrotechnicians for their own displays and some are obtained as required from a factory in N.S.W.

Thirteen Permits for Displays were issued during the year and each application required some special investigation of factors such as time, place, purpose of the display and the type of fireworks to be used. Some members of the public are very sensitive to the use of noisy fireworks at certain times and several complaints have been received by the Branch. On the other hand certain migrant communities hold traditional festivities in which loud explosive fireworks are considered to be an essential feature.

It is the policy of the Explosives Branch in granting Permits for Displays, to allow the migrant associations to celebrate in their own traditional way and at the same time control the displays in respect to noise and late hours thus reducing complaints to a minimum. The migrant communities regard noise as an essential part of certain festivals but it should be recorded that they are particularly co-operative in accepting limitations imposed by the Branch and are always anxious to avoid any offence to the general public.

EXPLOSIVES CONFERENCE

The Ninth Conference of Chief Inspector of Explosives of the Australian States and New Zealand was held in Tasmania from 26th March to 4th April and was attended by the Chief Inspector for Western Australia. New Zealand and Western Australia each had one representative and all other States had two delegates at the Conference. A lengthy agenda formed the basis for discussion of many items of mutual interest and a more uniform approach to the regulation and control of explosives will undoubtedly be achieved by such Conferences. The proceedings opened in Hobart and concluded in Launceston after an extensive tour through the West Coast mining areas where visits were made to Mt. Lyell, Renison Bell, Rosebery, Mt. Cleveland and Savage River. Government explosives reserves were inspected in Hobart and Launceston and the manufacture of slurry explosive was seen at Savage River.

At the conclusion of the Conference the writer proceeded to Melbourne in order to visit the Deer Park explosives factory of I.C.I.A.N.Z. Limited and the new Commonwealth Explosives Reserve at Point Wilson.

Delegates at the Conference agreed that they would be willing to visit Perth for the Tenth Conference and the Hon. Minister has since confirmed that Western Australia will extend a welcome to the visitors in October, 1970.

ACCIDENTS

Explosives

No serious accident with mining explosives was reported to the Explosives Branch during this year.

Laboratory Explosion

Investigation was made into the cause of an explosion in a chemical laboratory at Kalgoorlie. It was at first thought to have been caused by an accumulation of perchlorate salts on the porous base of the fume cupboard but, after inspection of the extensive damage, it was considered more probable that acetylene gas leaked from a cylinder alongside the fume hood and that the explosive mixture with air was ignited by the hot plate or the burner. Recommendatios were made to avoid any further accident with acetylene and to prevent the accumulation of perchlorate residues.

Pumping Crude Oil

At Barrow Island crude oil was being pumped from an underwater pipe-line into two 3,000 gallon tanks mounted on a vehicle. The pump was operated by a small diesel engine also mounted on the vehicle between the two tanks. Barrow Island crude oil is a Class 1 liquid with a flash point below 0°F. It therefore presents a flammable hazard equal to that of motor spirit.

When a spillage occurred from either the tank or its connections, vapours caused the diesel engine to race and emit sparks which ignited the highly flammable oil. The vehicle was gutted, one man died from burns and another man was seriously burned but recovered in hospital.

Inspector H. Douglas visited Barrow Island and prepared a formal report of his investigation which was submitted as evidence at the Coroner's Inquest. The Coroner subsequently made a recommendation that legislation be promulgated to ensure safeworking practice on oilfields in Western Australia with regulations based on the report of the Explosives Branch. The Coroner also expressed his appreciation of the investigation and the report prepared by Mr. Douglas.

FLAMMABLE LIQUIDS

The Flammable Liquids Regulations were completed and gazetted in May 1967 but the date of operation was deferred until November 1968. The continued lack of the necessary staff and office facilities made it necessary for the date of operation to be again deferred until 1st November 1969, but during this year sufficient progress has been made to ensure that there will be no further delay.

An inspector has been appointed and provision is made for three further appointments next year. The office has moved to larger premises with better facilities and preliminary work has been done on preparation of registration forms and information circulars. A system of licensing is being worked out and forms will be printed during the early months of 1969. It is intended that registration of premises will commence during the second half of the coming year so that licences can be issued by the time the regulations are in force.

Throughout this year the Branch has received many enquiries regarding the application of the Regulations to particular problems of storage and it is pleasing to report that the regulations appear to provide adequately for all situations. The co-operation of the major Oil Companies and of other industries is also recorded with appreciation. Even after the regulations are in force and licences issued, it will be several years before the full value of this work becomes effective.

INTERSTATE COMMITTEES

Australian Port Authorities Association.—A meeting of the Dangerous Goods Sub-Committee of the A.P.A.A. was held in Sydney on July 10th-11th. The Chief Inspector attended with the Harbour-Master for the Port of Fremantle.

Australian Dangerous Goods Transport Committee.—A meeting held in Melbourne on 15th August was attended by the Chief Inspector.

Australian Standards Association.—Mr. H. Douglas was appointed as representative for W.A. on the Committee dealing with Static Hazards in Industry. Mr. Douglas attended a meeting of the Committee in Melbourne on 25th November.

INVESTIGATIONS

Power Operated Machinery in Hazardous Locations.—Numerous enquiries were received by the Branch for details of power operated machines, mainly forklifts, which would be approved in various hazardous goods stores or in magazines. It therefore seemed necessary to formulate some general rules and recommendations which would provide a uniform basis for answering such enquiries. Mr. H. Douglas made a thorough investigation of these matters and was assisted by information supplied by agents and distributors for the equipment. The result was the publication of an information sheet which could be distributed to all those seeking guidance on the type of machine suitable for certain locations and the safety measures required.

Distress Signal Flares.—The Harbour and Lights Department require in their regulations that boats be equipped with pyrotechnic distress signal flares. Some of these were found to be unreliable in performance and it is now general procedure to submit new brands of signals to the Explosives Branch for testing and evaluation to the Board of Trade Specification. It will be necessary for the Branch to purchase a luminosity meter so that light intensity of flares can be measured.

GENERAL

The Explosives Branch continues to offer assistance to the Police Department on questions relating to explosives, dangerous goods and causes of fire. The storage and shipment of ammonium nitrate is constantly recurring and, although not classified explosive or declared to be dangerous goods, this substance requires more time and attention from the Explosives Branch than any of the Authorised Explosives.

At the close of this year the Explosives Branch had moved into new office premises and was well prepared to advance into the new field of Flammable Liquids. There is still much preliminary work to be done but all members of the present staff have shown exemplary enthusiasm for the task. When further inspectors are appointed it is hoped that the work will continue in the same tradition of combining the care of public safety with an intelligent regard for the needs of industry.

G. A. GREAVES,
Chief Inspector of Explosives.

DIVISION IX

Report of Superintendent, Mine Workers' Relief Act, and Chairman, Miners' Phthisis Board—1968

Under Secretary for Mines:

1. I submit for the information of the Honourable Minister for Mines my report on this Branch of the Mines Department for the year, 1968.

2. *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, the Perth Chest Clinic and in conjunction with the mobile X.ray Unit which visited the Coolgardie, Phillips River and Dundas Goldfields and the principal leases at Kalgoorlie on the East Coolgardie Goldfield.

3. *Mine Workers' Relief Act*

3.1 *Total Examinations*

The examinations under the Mine Workers' Relief Act during the year totalled 3870 as compared with 2029, the previous year, an increase of 1841. The results of examinations are as follows:

Normal	3,364
Silicosis early, previously normal	39
Silicosis early, previously silicosis early	431
Silicosis advanced, previously normal	Nil
Silicosis advanced, previously silicosis early	18
Silicosis advanced, previously silicosis advanced	3
Silico-tuberculosis, previously normal	Nil
Silico-tuberculosis, previously silicosis early	1
Silico-tuberculosis, previously silicosis advanced	1
Silico-tuberculosis, previously tuberculosis	Nil
Tuberculosis, previously normal	1
Asbestosis early, previously normal	3
Asbestosis early, previously asbestosis early	2
Asbestosis advanced, previously normal	Nil
Asbestosis advanced, previously asbestosis early	Nil
Silico-asbestos early, previously normal	2
Silico-asbestos early, previously asbestosis early	Nil
Silico-asbestosis early, previously silicosis early	1
Silico-asbestosis early, previously silico-asbestosis early	1
Silico-asbestosis advanced, previously silico-asbestosis early	1
Silico-asbestosis advanced, previously silicosis early	2
Silico-asbestosis plus tuberculosis, previously normal	Nil
Silico-asbestosis advanced plus tuberculosis previously silico-asbestosis early	Nil
Total	3,870

These 1968 figures, together with the figures for the previous years are shown on the table annexed hereto. Graphs are also attached illustrating the trend of examinations since 1940.

3.2 *Analysis of Examinations*

In explanation of the examination figures, I desire to make the following comments:—

3.2.1 *Normal, etc.*

These numbered 3,364 or 86.93% of the men examined and include men having first class lives or suffering from fibrosis only. The figures for the previous year being 1,644 or 81.02% of the men examined.

3.2.2 *Early Silicosis*

These numbered 470 of which 39 were new cases and 431 had previously been reported, the figures for 1967 being 351 and 19 respectively. Early silicotics represent 12.14% of the men examined, the percentage for the previous year was 17.15%.

3.2.3 *Advanced Silicosis*

There were 21 cases reported of which 18 advanced from early silicosis and 3 were previously reported. Advanced silicotics represent 0.54% of the men examined the percentage for the previous year being 0.39%.

3.2.4 *Silicosis Plus Tuberculosis*

Two cases were reported which was three less than in 1967.

3.2.5 *Tuberculosis only*

One case was reported compared with two in 1967.

3.2.6 *Asbestosis*

Five cases of early asbestosis were reported, three being new cases and two were previously reported. There were no cases of asbestosis advanced.

3.2.7 *Silico-Asbestosis*

Seven cases were reported of which two were new cases.

4. *Mines Regulation Act*

4.1 *Total Examinations*

Examinations under the Mines Regulation Act totalled 3,878. These were in addition to the 3,870 under the Mine Workers' Relief Act. There was an increase of 616 examinations under this Act in

1968 as compared with 1967. Of the total of 3,878 examined, 3,476 were new applicants and 402 re-examinees. In addition, Provisional Certificates were issued to 754 persons in isolated and country areas.

4.2 *Analysis of Examinations*

Particulars of examinations are as follows:—

4.2.1 *New Applicants*

Normal	3,454
Silicosis early	2
Silicosis early with tuberculosis	Nil
Tuberculosis	Nil
Other conditions	20
Total	3,476

4.2.2 *Re-examinees*

Normal	401
Silicosis early	Nil
Silicosis early with tuberculosis	1
Tuberculosis	Nil
Other conditions	Nil
Total	402

These men had been previously examined and some were in the Industry prior to this examination.

4.3 *Health Certificates Issued to New Applicants and re-examinees*

The following health certificates were issued under the Mines Regulation Act:—

Initial Certificates (Form 2)	3,842
Temporary Rejection Certificates (Form 3)	1
Rejection Certicates (Form 4)	22
Re-admission Certificates (Form 5)	9
Special Certificates (Form 9)	4
Total	3,878

5. *Miners' Phthisis Act*

The amount of compensation paid during the year was $12,425.00 compared with $13,571.00 for the previous year.

The number of beneficiaries under the Act as on 31st December, 1968, was 56, being 6 ex-miners and 50 widows.

6. *Administrative*

On 3rd December, 1968 Mr. W. A. Barnett, Secretary of the Mine Workers' Relief Board retired after some thirty-six years service in such capacity and at present his position is being filled by Mr. R. G. Tillotson.

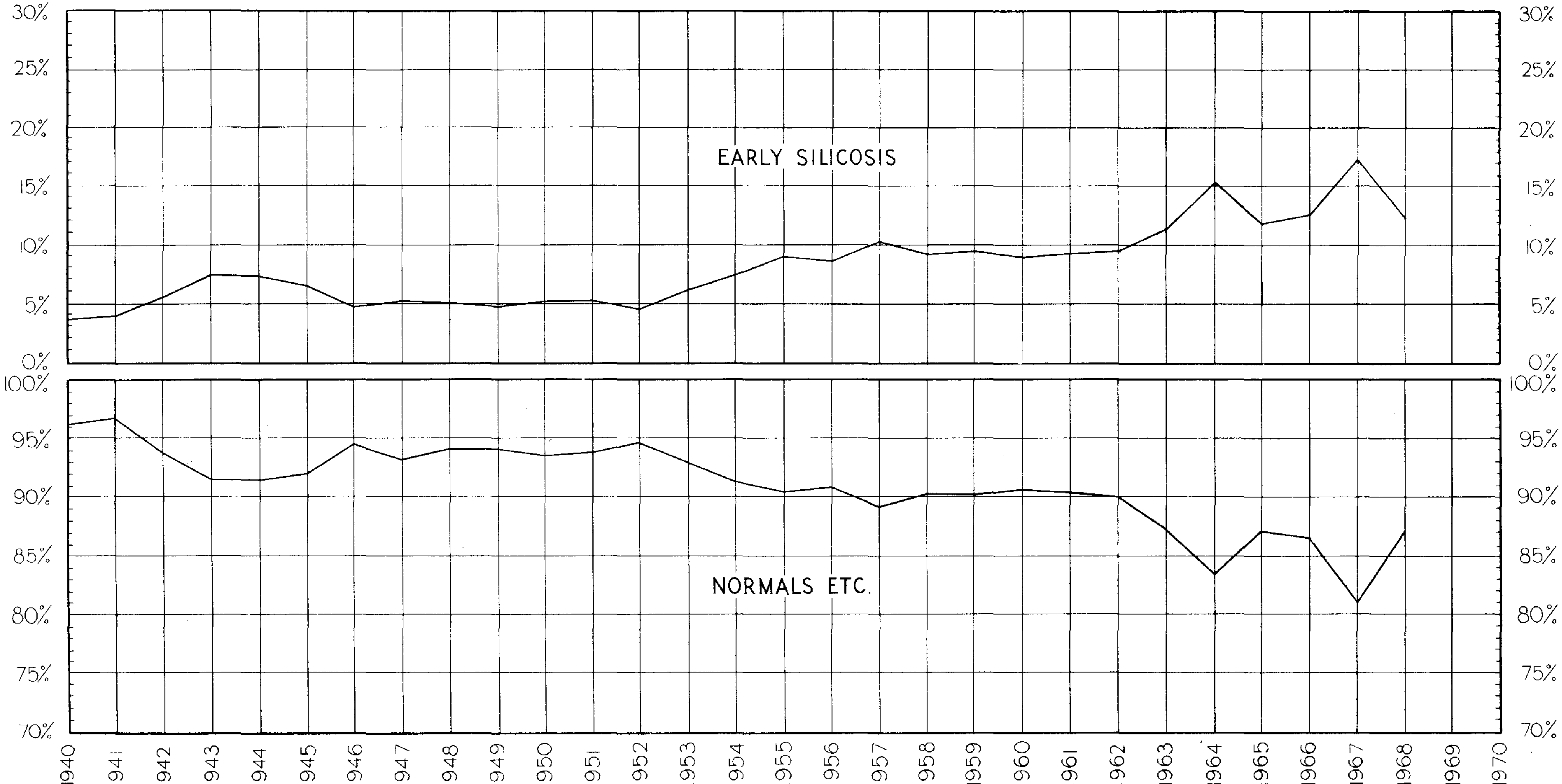
There were no other administrative changes during the year.

A. L. DAY,
Superintendent Mine 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



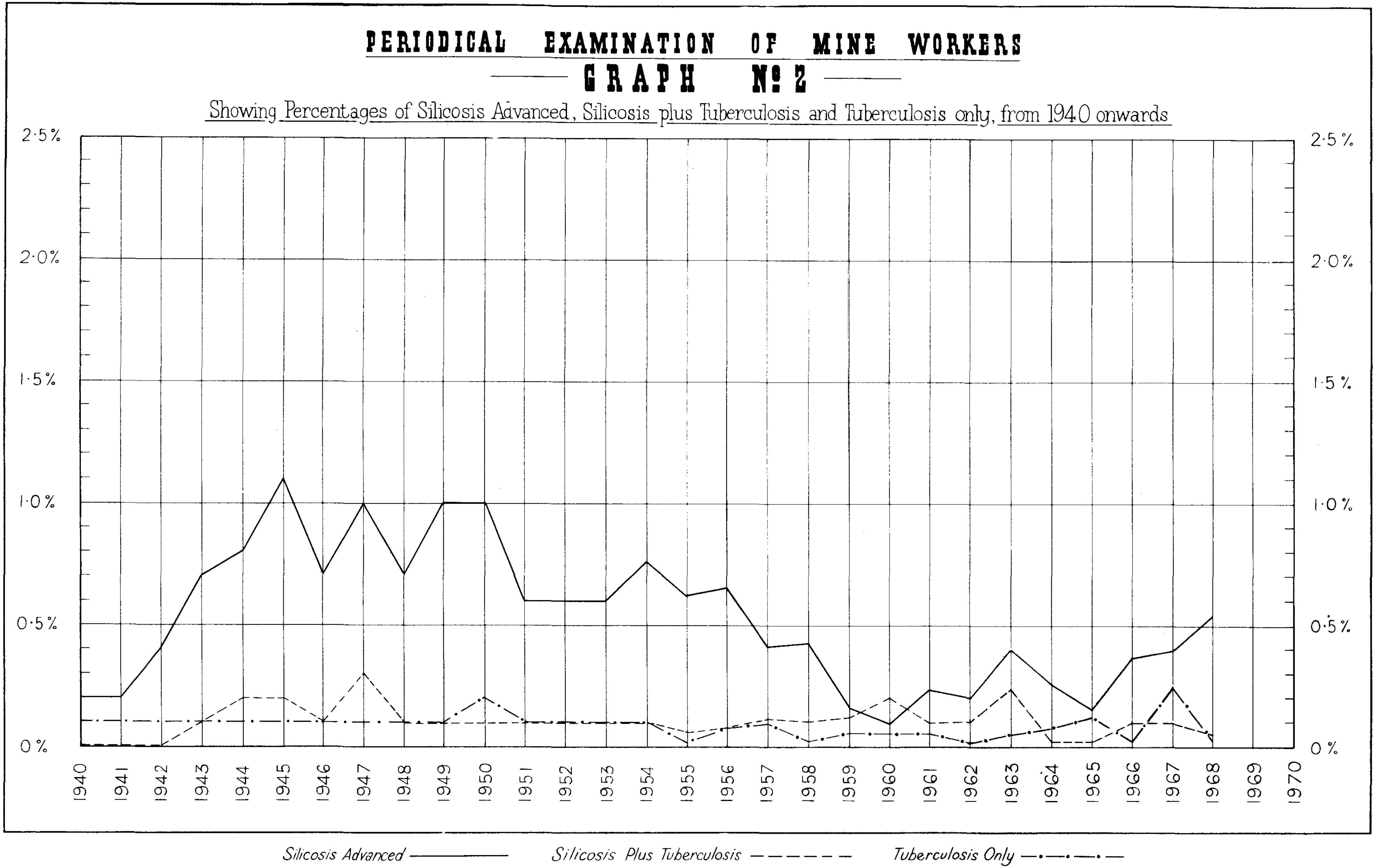

PERIODICAL EXAMINATION OF MINE WORKERS
GRAPH Nº 2
Showing Percentages of Silicosis Advanced, Silicosis plus Tuberculosis and Tuberculosis only, from 1940 onwards
2·5%
2·0%
1·5%
1·0%
0·5%
0%
1940
1941
1942
1943
1944
1945
1946
1947
1948
1949
1950
1951
1952
1953
1954
1955
1956
1957
1958
1959
1960
1961
1962
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
1967	1,644	81·03	19	332	351	17·30	....	7	1	8	·39	....	2	....	2	·10	5	·24	8	6	....	5	....	....	....	19	·94	2,029
1968	3,364	86·93	39	431	470	12·14	....	18	3	21	·54	....	1	1	2	·05	1	·03	5	4	....	3	....	....	....	12	·31	3,870

DIVISION X

Report of the Superintendent Surveys and Mapping for the Year 1968

The Under Secretary for Mines:

For the information of the Hon. Minister, I submit my report on the activities of the Surveys and Mapping Branch for the year ended 31st December 1968.

Generally, due partly to inadequate staff increase; and despite overtime being worked, the Branch is still unable to adequately cope with the charting, surveying and mapping requirements of the Department.

Plans available for inspection by the public at Head Office and the 16 District Offices are inadequate and need replacement.

In addition I have had to absorb the mapping requirements of the newly proclaimed Petroleum (Submerged Lands) legislation.

Accommodation is still scattered and unsatisfactory but officers are anticipating occupation of the new building with enthusiasm.

STAFF

The membership of the staff now totals 64 officers comprising 59 males and 5 females.

On July 12th, under the Public Service Professional Division (Drafting Officers) Salaries Agreement No. 31 of 1968, a new range of drafting salaries was determined, and the erstwhile name of the Survey Examination and Drafting Branch was changed to Surveys and Mapping Branch.

Simultaneously the titles of Chief Draftsman and Assistant Chief Draftsman were altered to Superintendent and Assistant Superintendent respectively.

During the year, one Level 3, three Level 2 (Drafting), one Technical and five Clerical positions were created, thus expanding the staff structure, but unfortunately this was offset to some degree by nine resignations and one, two year secondment.

Itemised reports of the activities of the various sections of the Branch are appended hereto.

A. A. HALL,
Superintendent.

SURVEYS

During the year an amount of $62,518 was paid to the Department's contract surveyors as against $64,980 for the previous year.

Surveys during the year were carried out at the following centres:—

South-West Mineral Field

Yoganup.
Wanneroo.
Koolanooka.
Clackline.
Willow Springs.
Wheatley.
Rockingham.
Mt. Hallowell.
Toodyay.

Broad Arrow Goldfield

Gudarra.
Smithfield.
Broad Arrow.
Black Flag.
Bardoc.
Scotia.

Coolgardie Goldfield

Coolgardie.
Burbanks.
Emu Rocks.
Spargoville.
Widgiemooltha.

North Coolgardie

Binti Binti.

North East Coolgardie

Carr Boyd Rocks.
Gindalbie.
Emu Lake.
Kanowna.

Phillips River Goldfield

Ravensthorpe.
Kundip
Bandalup.
Fitzgerald River.

Pilbara Goldfield

Pilgangoora.
Marble Bar.
Fieldings Gully.
Warrawoona.
Moolyella.
Talga Talga.
Soansville.
Mt. Fraser.
Shaw River.
Split Rock.
Cooglegong.
Nullagine.
Barton.
Blue Bar Pool.
Upper Five Mile Creek.
Upper Castle Creek.

West Pilbara Goldfield

Balla Balla.
Glenroebourne.
Yannery Hill.
Mt. Tom Price.
Nickol Bay.
Pilbara.
Station Peak.
Mt. Newman.

Murchison Goldfield

Gabanintha.
Abbotts.
Chesterfield.
Wadgingarra.
Mt. Magnet.
Lennonville.

Northampton Mineral Field

Northampton.
Baddera.

Dundas Goldfield

Norseman.
Princess Royal.
Mt. Thirsty.

The total number of surveys, under the Mining Act, completed during the year was 539 representing a surveyors account total of $97,902 from which an amount of $2,400 was deducted for drafting fees.

The surveys were performed by the following surveyors:

Surveyor.	Number of Surveys.
K. J. Croghan	115
P. J. Hille	93
M. M. Fisher	88
F. R. Rodda	63
M. J. McKimmie	58
J. A. Jamieson	51
K. H. Piper	30
D. D. Murray	17
E. Brook	9
L. J. Burkett	2
D. Considine	1
G. Pascott	1
"Compiled"	11

Four special surveys were undertaken during the year as follows:—

1. *Temporary Reserve 3666H.*—This reserve extends from Kambalda southwards to about Higginsville and is covered by the special legislation "Nickel Refinery (Western Mining Corporation Limited) Agreement Act, 1968."

The reserve contains about 527 square miles and to the end of 1968 approximately 89¼ miles of the boundaries had been established by conventional survey. Thus leaving approximately 17½ miles of boundary to be run. The Surveyor on this project is K. H. Piper.

2. *Temporary Reserve 4326H.*—The northern boundary and datum peg of this reserve, situated near Mt. Newman, was required to be set out on the ground. This survey was performed by E. Brook.

3. *Hamersley Range Iron Ore Leases.*—One of our problems for several years now has been a method of establishing the boundaries of this 300 square mile lease (in 231 sections). Photogrammetric techniques appear to offer a solution and accordingly the approval of the Surveyor General was sought, and obtained, and a Photogrammetric survey has been commenced embracing 69 of the Sections. These are situated in the vicinity of, and westwards from, Mt. Tom Price. This is the first time this technique has been used in W.A. and the results and costs are being carefully evaluated. The project consists of the following essential processes:—

(1) Ground mark and target all the lease corners and with certain intermediate marks as required.

(2) Identify these on photographs.

(3) Place ground control by conventional survey—tellurometer was used in this instance.

(4) Photograph the area from the air.

(5) Identify all pre-marked positions and control points, on the photos.

(6) Obtain co-ordinates of all positions thus established.

(7) Record and certify the results in diagram form.

To the end of 1968, the steps (1) to (5) had been successfully completed. The ground marking has been done by K. J. Croghan, while the Photogrammetric survey is being done by Australian Aerial Mapping.

4. *Mt. Newman Iron Ore Lease.* The problem here is similar to that for the Hamersley Range Leases except that the Newman 300 square mile lease is much more compact and not as widely distributed as the Hamersley Lease. The method finally adopted in this case has been to—

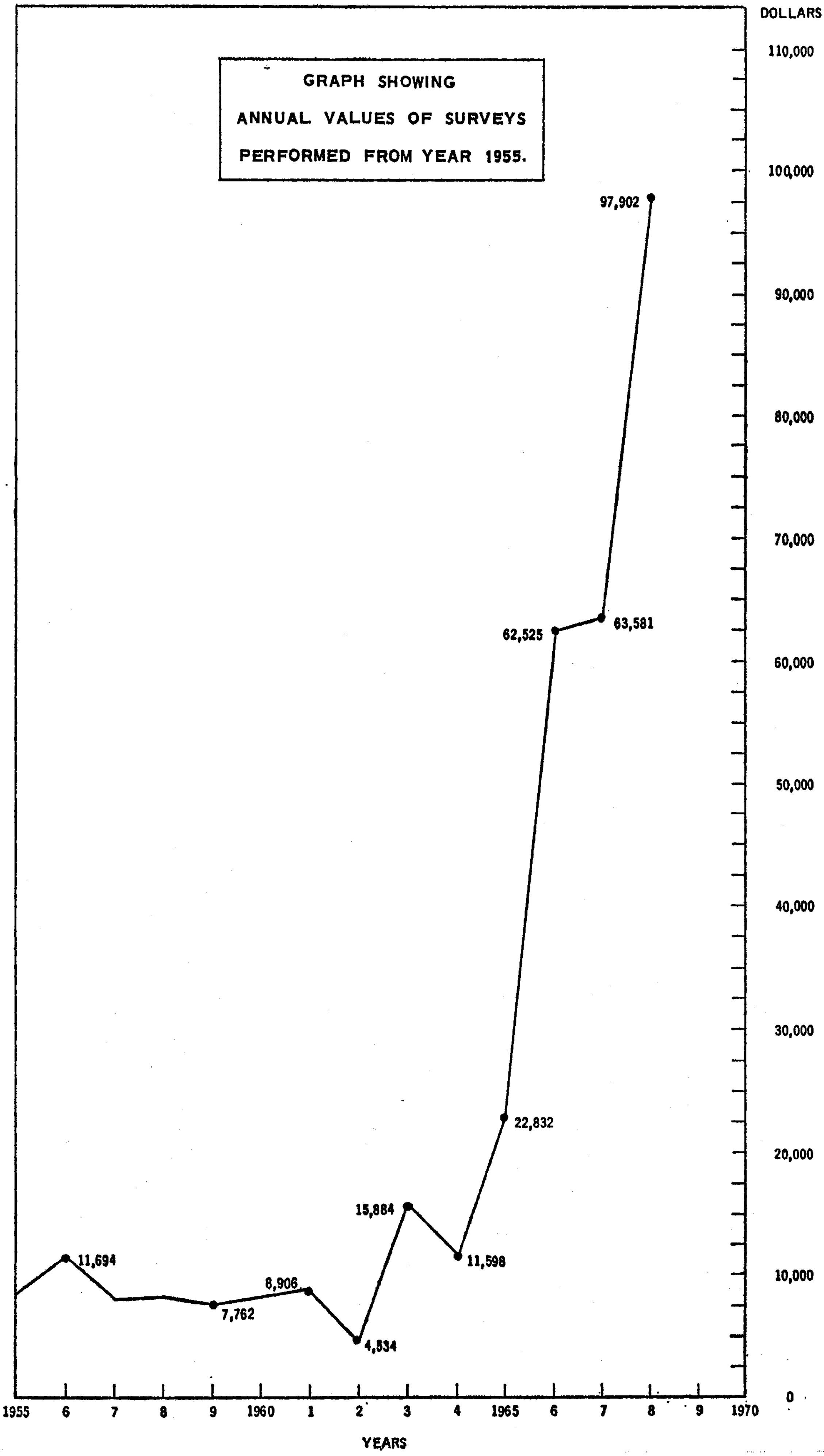
(1) establish all the lease corners on the plan by co-ordinates relative to an origin or starting point.

(2) set out a tellurometer control survey establishing ground stations in vicinity of each purposed corner.

(3) comparing the station co-ordinates with corner co-ordinates.

(4) setting out and marking the lease corner therefrom.

This survey is being performed by the B.H.P. as agents for the lessees with surveyor E. Brook providing independent certification.



DOLLARS
110,000
100,000
90,000
80,000
70,000
60,000
50,000
40,000
30,000
20,000
10,000
0
GRAPH SHOWING
ANNUAL VALUES OF SURVEYS
PERFORMED FROM YEAR 1955.
97,902
62,525
63,581
22,832
15,884
11,694
11,598
8,906
7,762
4,534
1955
6
7
8
9
1960
1
2
3
4
1965
6
7
8
9
1970
YEARS

SURVEY EXAMINATION

We commenced the year with a carry over of 370 surveys unexamined from 1967. Add to this the 539 surveys completed in the field during 1968 and subtract 333 surveys examined during the year giving a carry over of 576 surveys unexamined.

Original and duplicate plans were prepared on lease instruments and diagrams of surrender and resumption were prepared as required.

Survey instructions and necessary information relating to survey details were supplied to surveyors in the field as required.

GEODETIC

Once again this year no calculations (apart from certain sheet corner assessments) were made for standard plans, the staff being concentrated on survey and diagram work, with the result that the geodetic work has accumulated.

PETROLEUM

During the year the new Commonwealth-State uniform offshore petroleum legislation was proclaimed and a special drafting section was established to handle this work. Work during the year consisted of—

(1) preparation of a set of maps showing the identification of the graticular sections in the Adjacent Area and published at scale 1: 1,000,000. There are 16 maps in this series and 12 were published during the year;

(2) preparation of a set of public and working plans based on this series showing permit boundaries;

(3) calculation of the oblique line intersection with each five minute graticule on the geoid;

(4) preparation of technical descriptions of all permits in the adjacent area;

(5) prepartion of new map of the State at scale 1: 4,000,000 showing tenements under the Petroleum Acts;

(6) maintenance of all Drafting Branch records and dealings concerning the Petroleum Acts.

Following is a summary of tenements under the Petroleum Acts:—

Tenement	Applications received in 1968	Tenements in force at 31st Dec., 1968
Exploration Permits	42	36
Permits to Explore	5	32
Licences to Prospect	23	55
Petroleum Leases	0	2

MAPPING

The Mapping programme covers two main areas, that of Standard Mapping and Geological Mapping.

(1) Standard Mapping

1:50,000

Twenty-four new public plans were prepared on this scale over various areas of the State as follows:—

Wangine 3037-1, Ringlock 3137-1, Broad Arrow 3137-11, Ora Banda 3137-111, Scotia 3137-1V, Gidge 3136-1, Kalgoorlie 3136-11, Coolgardie 3136-111, Kunanalling 3136-1V, Woolgangie 3035-1V, Gibraltar 3036-1, Burbanks 3135-1V, Marion 3135-1, Larkinville 3135-11, Burra Rock 3135-111, Wanaway 3134-1, Mandu 1653-1, Bundera 1653-11, Yardie 1614-11, Rough Range 1753-111, Learmouth 1753-1V, N.W. Cape 1754-111, Breakaway, Mt. Walter.

In addition, 24 sheets covering the Menzies 1:250,000 sheet were commenced.

The Standard programme was continued with new ones being drawn and the increase in Survey work resulted in 170 new surveys being plotted on standards.

(2) Geological Mapping

1:50,000 Maps

The Northampton sheet was published at the Government Printing Office and the remaining 5 sheets of this area brought to Printers Proof stage.

1:250,000 Maps

This programme continued and during the year Yarraloola and Turee Creek were printed by Mercury Press (Tasmania) and Edmund and Kalgoorlie were despatched for printing. Culver, Loongana, and Naretha were completed and work proceeded on Wyloo and Balladonia.

Nine sheets were commenced in Madura-Burnabbie, Eucla-Noonaera, Seemore, Mason, Menzies, Scott, Cooper, Talbot, and Bentley. The sheets of Plumridge, Forrest, Jubilee and Zanthus were temporarily suspended.

1:2,500,000

The new State Base Map proceeded and was brought near to completion ready for photography.

A new Geological Map was commenced using the new base map above.

Bulletin

Geological Bulletin 119 showing the Crocidolite deposits of the Hamersley area was commenced. This involves 12 colour plates and 34 black and white plates.

Technical Plans

Over 200 technical plans were drawn for Geological Surveys and other Departments, together with 8,200 prints and 3,700 involving photography.

PUBLIC PLAN SECTION

During the year the following applications were charted on public plans:—

Mining Tenements (P.A.'s M.C.'s M.L.'s etc.)	6,015
Temporary Reserves	467

A total of 7478 plans were produced during the year for Head Office and outstations, for sale and working plan purposes, of which 1645 were distributed, for outstation and inter-departmental use.

Head Office plan sales netted $5840.00 for the year.

In addition numerous special purpose plans were prepared for departmental and inter-departmental use.

A total of 690 searches to determine land tenure and mineral ownership have been carried out, representing a decrease of approximately 25 per cent. on the previous year. This decrease mirrors an amendment of departmental policy on searching.

The 24 sheets of the 1:50,000 series, outlined under the Mapping Section, have been incorporated into the public plan system bringing the total of public plans under maintenance to 987. The life span of some of these plans in the most densely active areas being as little as 6 weeks.

MINING STATISTICS
to 31st December, 1968

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TABLE I

PRODUCTION OF GOLD AND SILVER AS REPORTED TO THE MINES DEPARTMENT DURING 1968.

(For details concerning Mines and Centres not listed see Annual Report for 1966 or previous Reports.)

(*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.)

Mining Centre	Number of Lease	Registered Name of Company or Lease	Total for 1968					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.												
MARBLE BAR DISTRICT.												
Bamboo Creek	G.M.L. 1118	Kitchener	....	....	309·25	556·73	....	....	....	908·50	1,365·90	3·53
	1203	Mt. Prophecy	....	....	766·75	325·93	....	....	....	3,063·05	1,846·38	88·14
	1095, (1096), (1097)	Mt. Prophecy Leases	....	....	110·50	22·70	....	....	24·50	3,163·50	1,119·42	49·63
	1216	Prince Charlie	....	....	119·75	26·72	....	....	....	221·00	118·61	....
Marble Bar	....	Sundry Claims	....	....	88·50	29·90	....	67·08	255·30	21,838·79	12,929·24	10·96
Pilgangoora	....	Sundry Claims	....	....	5·00	16·93	....	161·08	47·76	635·10	365·89	·25
Wymans Well	1084	New Copenhagen	....	....	168·75	19·06	....	....	....	939·30	184·58	4·34
Yandicoogina	....	Sundry Claims	....	3.03	35·00	3·71	....	4·32	242·92	682·25	697·37	47·51
		State Battery, Marble Bar	....	....	....	*334·16	80·32	....	....	12·00	*13,810·52	356·70
NULLAGINE DISTRICT.												
Nullagine	....	Sundry Claims	....	....	156·00	29·79	....	321·36	689·71	6,875·20	10,620·70	18·75
Gascoyne Goldfield.												
Mangaroon Station	G.M.L. 46	Star of Mangaroon	....	....	662·00	741·29	....	....	3·50	2,023·75	3,092·82	60·25
Peak Hill Goldfield.												
Peak Hill	....	Sundry Claims	....	10·01	....	....	....	61·51	393·87	35,365·35	9,030·99	5·35

East Murchison Goldfield.

LAWLERS DISTRICT.

Sir Samuel	G.M.L. 1392	Jackpot	....	13·40	....	....	....	....	13·40	....	....	....
Wildara Station	1389	Butcher Bird	....	....	597·50	157·01	....	....	....	1,219·50	420·15	....
	1388	Tahmoo	....	....	192·25	78·50	....	....	....	1,463·25	440·50	....
		Sundry Claims	....	....	100·00	19·39	....	143·23	....	1,511·75	765·79	29·71

BLACK RANGE DISTRICT.

Barrambie	G.M.L. 1124B ..	Barrambie Range	....	....	47·75	122·84	....	....	....	67·50	130·77	·58

Murchison Goldfield.

CUE DISTRICT.

....	....	State Battery, Cue	....	....	....	*163·39	7·84	....	....	76·25	*27,609·55	163·10
....	....	Reported by Banks and Gold Dealers	7·45	....	....	....	·29	3,464·96	109·87	....	22·62	2·10

MEEKATHARRA DISTRICT.

Chesterfield	....	Sundry Claims	....	2·15	15·00	35·29	....	....	44·34	1,175·05	826·12	1·22
Meekatharra	G.M.L. 2015N ..	Haveluck	....	....	1,649·00	165·56	....	....	....	1,649·00	165·56	....
		Reported by Banks and Gold Dealers	1·38	....	....	....	....	12,315·47	297·96	451·50	97·71	10·55

DAY DAWN DISTRICT.

Day Dawn	....	Sundry Claims	....	....	114·50	6·42	....	96·42	523·56	13,775·01	6,780·27	2·89

MOUNT MAGNET DISTRICT.

Lennonville	G.M.L. 1652M	Long Reef South Extended	....	....	39·75	2·13	....	....	....	39·75	2·13	....
		Sundry Claims	....	8·15	18·50	1·68	....	26·00	116·97	15,555·77	6,065·00	11·07
Mt. Magnet	1670M	Black Cat	....	....	28·30	2·90	....	....	....	28·30	2·90	....
	1527M	Eclipse Gold Mine N.L.	....	....	....	28·76	....	....	12·20	36,408·00	42,200·27	4,660·44
		Prior to transfer to present holders	....	....	....	....	....	....	....	294·10	170·77	1·34
	1282M, etc.	Hill 50 Gold Mine N.L.	....	....	127,025·00	32,455·85	2,480·69	....	....	2,812,763·40	1,260,128·24	61,938·81
		Prior to transfer to present holders	....	....	....	....	....	....	829·41	8,787·65	4,122·61	·21
	1654M	Susan Jane	....	....	6·00	17·14	....	....	....	14·00	30·85	·45
		Sundry Claims	....	3·02	333·25	46·52	·03	157·95	2,629·26	62,209·17	30,281·16	29·52
		Reported by Banks and Gold Dealers	3·45	....	....	....	....	2,328·46	114·69	8·00	113·15	·89

Yalgoo Goldfield.

Goodingnow	G.M.L. 1063	Ark	....	....	54·00	2·98	....	....	12·49	2,364·50	1,957·52	....
	1242	Carnation	....	....	283·50	123·32	....	....	....	391·50	182·57	....
	1243	Threybit	....	....	138·00	8·09	....	....	....	472·00	23·99	....
		Sundry Claims	....	....	181·50	56·40	....	152·96	169·70	10,871·55	5,224·21	·14
Noongal	....	Sundry claims	....	30·11	....	....	....	39·32	340·42	8,506·55	3,590·35	1·16

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 1968					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.
Mt. Margaret Goldfield.												
MOUNT MORGANS DISTRICT.												
Redcastle	....	Sundry Claims	....	....	12·00	3·13	....	....	113·84	1,231·57	662·07	....
MOUNT MALCOLM DISTRICT.												
Diorite	G.M.L. 1853C	Puzzle	....	....	370·00	486·26	....	....	....	370·00	486·26	....
		Sundry Claims	....	....	120·00	12·55	....	11·21	332·13	4,906·85	4,799·01	....
Lake Darlot	....	Sundry Claims	....	8·31	94·25	101·32	....	129·92	914·83	12,410·37	6,891·92	45·18
Leonora	1762C–67C	Sons of Gwalia Ltd.	....	18·73	....	....	....	....	18·73	7,030,740·53	2,581,184·62	188,812·19
		Prior to transfer to present holders	....	....	....	....	....	....	....	109,081·00	55,989·21	8·66
	1854C	Tower Hill	....	....	596·50	104·79	....	....	....	596·50	104·79	....
		Sundry Claims	....	....	179·00	40·03	....	37·73	377·26	23,733·45	13,030·23	26·77
Wilsons Patch	....	Sundry Claims	....	....	39·00	2·79	....	4·68	54·46	1,766·16	1,455·90	1·12
		State Battery, Lake Darlot	....	....	....	*410·56	....	....	....	18·00	*3,737·90	4·98
		State Battery, Leonora	....	....	91·00	*93·50	2·19	....	....	91·00	*195·22	6·45
		Reported by Banks and Gold Dealers	·30	....	....	....	....	3,653·84	252·83	47·00	59·57	·67
North Coolgardie Goldfield.												
MENZIES DISTRICT.												
Menzies	G.M.L. 5794Z	Callie	....	....	91·50	10·20	....	....	....	489·25	111·98	....
	5799Z	First Hit	....	....	71·50	26·66	....	....	....	748·00	108·79	....
	5804Z	Gladys Mary	....	....	263·00	9·39	....	....	....	263·00	9·39	....
		Sundry Claims	....	....	271·00	17·16	....	56·87	624·33	42,939·69	26,573·87	813·76
Mt. Ida	G.M.L. 5537Z,etc.	Moonlight Wiluna Gold Mines Ltd.	....	....	269·50	140·50	....	....	40·77	455,676·36	232,208·93	7,614·32
		Prior to transfer to Present Holders	....	....	....	....	....	....	....	31,833·25	16,021·98	891·37
		State Battery, Menzies	....	7·62	....	....	....	....	7·62	20·00	*3,820·83	1,032·66
ULARRING DISTRICT.												
Mulline	....	Sundry Claims	....	....	572·75	55·02	....	10·82	296·42	12,255·64	10,008·27	1·14
Mulwarrie	G.M.L. 1113U	Oakley	....	....	100·00	79·97	....	....	....	5,512·00	8,711·07	333·95
NIAGARA DISTRICT.												
Kookynie	....	Sundry Claims	....	....	15·75	4·40	....	60·92	106·60	9,602·30	7,000·34	4·19
YERILLA DISTRICT.												
Yilgangie	G.M.L.1176R,etc.	Western Mining Corporation N.L.	....	....	367·00	66·00	....	....	....	33,266·50	30,600·87	4,471·98
		Prior to transfer to present holders	....	....	....	....	....	....	·85	1,244·75	1,830·28	....
		Reported by Banks and Gold Dealers	·27	....	....	....	....	1,162·50	160·08	....	28·80	·09

Broad Arrow Goldfield.

Bardoc	G.M.L. 2333W	Patience	....	....	131·00	11·63	....	....	....	317·00	37·23	....
Broad Arrow	2342W	Balmoral	....	....	13·00	3·18	....	....	....	13·00	3·18	....
	2346W	Sunday Eve	....	....	117·25	145·61	....	....	....	117·25	145·61	....
		Sundry Claims	....	2·57	115·50	144·60	....	1,008·56	3,058·78	39,150·65	17,728·02	1·42
Cashmans	....	Sundry Claims	....	7·18	....	....	....	....	47·49	1,300·62	679·45	·05
Grant's Patch	2277W	Coronation	....	....	5·25	4·77	....	....	....	992·35	836·79	5·41
Ora Banda	2270W 2290W	Ora Banda Amalgamated Mines N.L.	....	....	310·50	11·40	....	....	....	48,363·00	5,792·97	164·62
	2315W	Victorious	....	....	100·00	4·28	....	....	....	1,246·00	53·32	....
		Sundry Claims	....	....	173·25	70·80	....	....	467·18	17,369·05	5,137·49	....
Siberia	....	Sundry Claims	....	....	64·75	447·22	....	289·06	1,261·72	21,498·34	13,348·08	....
		State Battery, Ora Banda	....	....	....	47·70	·32	....	....	128·05	28,645·40	108·26

North-East Coolgardie Goldfield.

KANOWNA DISTRICT.

Gordon	....	Sundry Claims	....	....	14·25	3·15	....	....	177·38	2,280·20	1,233·02	....
Kalpini	G.M.L. 1591X	Bank of Kalpini	....	....	67·50	6·82	....	....	....	67·50	6·82	....
		Sundry Claims	....	....	31·75	9·80	....	24·70	269·72	1,706·75	1,062·54	·16
Kanowna	1586X	Kanowna Red Hill	....	....	2,160·50	399·81	....	....	....	2,380·50	630·65	....
	1585X	New Kanowna	....	....	16·50	19·14	....	....	....	38·50	113·30	....
	1588X	Pick Handle	....	....	116·50	14·47	....	....	....	116·50	14·47	....
		Sundry Claims	....	....	26·00	10·24	....	125·32	2,169·07	28,838·82	12,304·08	1·71

KURNALPI DISTRICT.

Kurnalpi	....	Sundry Claims	....	....	33·75	1·32	....	324·12	727·39	4,658·61	2,384·58	....
		Reported by Banks and Gold Dealers	·17	....	....	....	....	12,108·51	70·70	....	2·35	1·49

East Coolgardie Goldfield.

EAST COOLGARDIE DISTRICT.

Binduli	....	Sundry Claims	....	....	51·50	·49	....	....	13·01	6,161·62	1,765·03	·34
Boorara	G.M.L. 6658E	Waterfall	....	....	207·00	82·47	....	....	....	310·00	138·30	....
Boulder	5345E,etc.	Gold Mines of Kalgoorlie (Aust.) Ltd.....	....	....	297,647·75	72,455·42	35,249·41	....	....	5,799,980·75	1,467,585·64	411,790·31
		Prior to transfer to present holders	....	....	....	....	....	....	849·95	15,916,923·07	6,416,710·17	819,123·27
	5695E,etc.	Great Boulder Gold Mines Ltd.	....	....	191,806·00	39,732·50	27,137·30	....	1·53	16,688,166·97	7,031,202·39	1,871,759·94
	5708E,etc.	Lake View & Star Ltd.	....	....	563,114·00	130,437·48	16,136·28	....	....	21,033,229·30	5,927,335·34	664,663·63
		Prior to transfer to present holders	....	....	....	....	....	....	8·49	15,792,500·38	9,149,223·80	1,348,055·82
	5431E,etc.	North Kalgurli (1912) Ltd.	....	....	348,692·00	63,578·47	28,579·97	....	127·55	8,645,517·24	2,179,884·44	625,360·28
	5405E,etc.	North Kalgurli (1912) Ltd. (Croesus Pty. Group)	....	....	....	....	....	....	51·20	90,519·00	19,261·22	....
		Prior to transfer to present holders	....	....	....	....	....	43·99	....	4,018,629·01	2,815,959·95	97,625·03

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 1968					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.*										
Hampton Plains....	P.P.L. 277, Loc. 50	Joyce & Africh	....	....	1,227·00	183·84	....	....	....	14,363·75	1,379·05	2·06
	P.P.L. 488, Loc. 48	L. Lethlean	....	....	5·50	15·85	....	....	....	21·25	42·19	....
	S.L. 1, Loc. 50	Western Mining Corpn. Ltd.	....	....	250·00	40·15	....	....	....	4,401·00	401·77	86·37
Kalgoorlie....	G.M.L. 6594E	Gledden South	....	....	21·00	28·98	....	....	....	81·00	77·84	....
	5510E	Golden Dream....	....	....	465·00	15·75	....	....	....	719·75	41·99	....
		Prior to transfer to present holders	....	....	....	....	....	....	....	530·74	149·77	....
	6537E	Golden Key	....	....	24·00	27·54	....	....	....	69·50	124·61	....
	6563E,etc.	Gold Mines of Kalgoorlie (Aust.) Ltd. (Mt. Charlotte Mine)	....	....	577,235·00	80,939·61	....	....	....	1,757,067·00	237,693·87	....
		Prior to transfer to present holders	....	....	....	....	....	....	5·72	85,723·60	18,167·21	171·56
	6091E	Lesanben	....	10·70	29·00	36·78	....	....	233·85	1,397·10	1,005·20	3·88
	6485E	Maritana Hill	....	....	230·75	39·69	....	....	....	3,562·00	445·12	....
	6615E	Middle Hannans	....	....	149·50	42·51	....	....	....	475·75	62·88	....
	6639E	Old Hinchcliffe	....	....	682·75	40·87	....	....	....	1,316·75	148·16	....
	5852E	Pedestal	....	....	36·50	25·97	....	....	....	1,800·00	491·33	....
	5852E, (6024E)	Pedestal Leases	....	....	....	....	....	....	....	1,828·50	490·37	....
		Sundry Claims	....	....	32·00	·93	....	232·41	1,124·98	63,917·12	23,481·70	·20
Wombola	G.M.L. 5497E, 5500E	Daisy Leases	....	....	483·25	904·68	....	....	....	23,549·20	21,220·88	884·76
	5497E	Daisy	....	....	....	....	....	....	....	6,282·25	5,031·93	....
	5500E	Happy-go-lucky	....	....	....	....	....	....	....	2,075·25	1,675·85	....
	6635E	Hodad	....	....	243·00	10·68	....	....	....	3,475·50	477·93	51·81
	6650E	Inverness	....	....	221·25	39·13	....	....	....	461·75	70·85	....
	6487E	Leslie	....	....	67·50	15·69	....	....	....	472·00	386·49	1·17
		Sundry Claims	....	....	120·75	65·32	....	....	711·10	26,397·68	14,678·39	·20
		State Battery, Kalgoorlie	....	....	....	*755·84	71·05	....	....	390·70	*40,301·11	597·59
		Regan, F. G. L.T.T. 4E/68 (1697H)	....	....	103·75	*5·90	....	....	....	103·75	*5·90	....
		Reported by Banks and Gold Dealers	4·87	2·90	....	....	....	17,023·56	10,077·52	430·68	7,639·49	....
		BULONG DISTRICT.										
Bulong	G.M.L. 1342Y	Rocket	....	....	35·50	30·93	....	....	....	150·75	196·32	....
		Reported by Banks and Gold Dealers	·02	....	....	....	....	25,225·24	70·15	·01	28·44	....

Coolgardie Goldfield.

COOLGARDIE DISTRICT

Bonnievale	G.M.L. 5986	Jenny Wren	....	....	8·00	1·91	....	....	....	449·00	252·13	·29
	5890	Rayjax	....	....	185·25	42·98	....	....	....	1,041·00	1,374·52	5·12
		Sundry Claims	....	46·37	1,439·50	99·68	....	....	285·28	11,189·13	5,753·56	1·11
Burbanks	(6058)	Belgian Queen	....	....	7·50	14·30	....	....	....	58·50	16·87	....
	6069	New Lord Bobs	....	....	54·50	13·44	....	....	....	54·50	13·44	....
		Sundry Claims	....	....	4·00	5·46	....	55·05	497·55	18,239·85	9,478·59	·93
Coolgardie	6043	Dryden	·88	....	....	....	....	·88	....	....	....	....
	6097	Garfield	....	....	4·00	6·12	....	....	....	4·00	6·12	....
	6109	Grace	....	....	1,312·75	61·37	....	....	....	1,312·75	61·37	....
	6038	Hillside	....	....	224·00	130·17	....	....	....	459·00	317·22	....
	6047	Predjudice	....	....	167·00	10·22	....	....	....	267·00	21·10	....
	6046	Valerie May	....	....	13·00	2·17	....	....	....	13·00	2·17	....
		Sundry Claims	....	52·76	501·25	102·18	....	236·14	3,044·77	86,972·94	29,856·67	1·90
Hampton Plains	P.P.L. 16A, Loc. 59	C. W. Avard	....	....	40·75	16·75	....	....	....	258·00	85·95	....
	P.P.L. 481, Loc. 59	T. R. Baker	....	....	185·00	19·49	....	....	....	573·00	110·03	....
	P.P.L. 490, Loc. 48	D. Rennie	....	....	25·50	6·54	....	....	....	81·00	34·78	....
Higginsville	G.M.L. 6121	Broken Bottle	....	....	84·00	34·01	....	....	....	84·00	34·01	....
	6061	Two Boys	....	....	54·50	46·29	....	....	....	710·25	216·56	....
	6016	Great Lion	....	....	83·00	·72	....	....	....	639·00	80·79	....
		State Battery, Coolgardie	....	....	....	*380·20	....	....	....	771·01	*42,618·68	29·26
		Reported by Banks and Gold Dealers	2·92	....	....	....	....	15,030·68	743·46	48·25	141·36	1·05

KUNANALLING DISTRICT.

Chadwin	....	Sundry Claims	....	30·34	75·00	13·80	....	14·28	136·74	6,129·05	3,023·97	·25
Jourdie Hills	....	Sundry Claims	....	....	14·00	1·92	....	1·86	49·81	2,071·50	929·21	1·05
Kintore	....	Sundry Claims	....	....	153·75	32·34	....	111·91	102·70	5,369·53	2,689·90	....
Kunanalling	G.M.L. 1052S	Catherwood	....	....	35·00	1·90	....	....	....	375·50	20·33	....
		Sundry Claims	....	17·49	26·00	3·97	....	216·53	994·36	17,084·27	10,300·66	....

Table I.—*Production of Gold and Silver from all sources, etc.*—continued.

Mining Centre	Number of Lease	Registered Name of Company or Lease	Total for 1968					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.												
Bullfinch	G.M.L. 4535	Casas	....	....	14·00	7·57	1·73	....	....	14·00	7·57	1·73
		Sundry Claims	....	....	15·00	1·74	·10	8·47	45·49	7,694·14	4,294·67	24·27
Eenuin	....	Sundry Claims	....	....	20·00	20·42	·97	3·16	90·95	2,893·95	2,072·46	5·36
Greenmount	G.M.L. 4543	Devs Reward	....	....	594·00	98·33	107·07	....	....	594·00	98·33	107·07
		Sundry Claims	....	....	217·00	25·25	15·83	·46	4·27	3,641·33	903·89	50·73
Hopes Hill	....	Sundry Claims	....	....	49·25	7·10	·88	21·12	96·11	4,932·87	1,482·63	2·49
Marvel Loch	G.M.L. 3724	Frances Firness	....	13·81	573·75	202·62	15·68	....	526·68	23,522·00	10,427·31	298·92
		Sundry Claims	....	....	19·00	2·67	....	11·35	809·31	38,904·34	13,925·63	86·02
Mt. Palmer	G.M.L. 4250	Palmerston	....	....	....	3·02	·15	2·03	1·69	857·50	182·31	1·91
Mt. Rankin	....	Sundry Claims	....	....	20·25	11·27	·62	....	1·85	835·00	999·61	1·69
Parkers Range	G.M.L. 4508	Buffalo	....	....	118·25	19·96	·56	....	10·36	990·00	180·17	5·30
	4512	Constance Una	....	....	110·75	412·77	30·89	....	....	965·00	1,883·53	84·50
Southern Cross	....	Sundry Claims	....	....	12·75	3·76	1·66	95·90	650·03	8,745·41	2,754·87	9·59
		State Battery, Marvel Loch	....	....	....	*285·99	1,661·80	....	....	147·00	*3,837·77	1,941·67
		Sellen, F. E. L.T.T., 1686H	....	....	....	*1·29	....	....	....	....	*1·29	....
		Reported by Banks and Gold Dealers	....	·47	....	....	....	325·29	81·88	·60	170·54	....
Dundas Goldfield.												
Beete	G.M.L. 2044	Beete	....	....	13·00	7·07	·46	....	....	13·00	7·07	·46
Norseman	1936, etc.	Central Norseman Gold Corporation, N.L.	....	....	177,275·00	84,016·04	71,966·80	....	....	4,511,884·20	2,122,478·46	1,429,023·76
		Sundry Claims	....	....	60·50	2·92	·03	1,052·25	3,523·62	49,864·45	22,645·03	228·10
		State Battery, Norseman	....	....	....	*68·70	3·65	....	....	427·89	25,950·29	1,090·84
Phillips River Goldfield.												
Kundip	G.M.L. 277	Western Gem	....	....	480·00	89·51	....	....	....	480·00	89·51	....
Ravensthorpe	M.C.'s 35, etc.	Ravensthorpe Copper Mines, N.L.	....	....	....	§1,128·56	3,805·61	....	....	....	§19,062·58	58,465·55
		Prior to transfer to present holders	....	....	....	....	....	....	....	....	§1·99	....

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 1968.

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	....	....	....	....	....	....	....	....	....	....	....	....	....
West Kimberley	....	....	....	....	....	....	....	....	....	....	....	....	....
West Pilbara	....	....	....	....	....	....	....	....	....	....	....	....	....
Pilbara	Marble Bar	....	3·03	1,603·50	1,335·84	1,338·87	80·32	....	3·03	1,759·50	1,365·63	1,368·66	80·32
	Nullagine	....	....	156·00	29·79	29·79	....						
Ashburton	....	....	....	....	....	....	....	....	....	....	....	....	....
Gascoyne	....	....	....	....	....	....	....	....	....	662·00	741·29	741·29	....
Peak Hill	....	....	....	....	....	....	....	....	10·01	....	....	10·01	....
East Murchison	Lawlers	....	13·40	889·75	254·90	268·30	....	....	13·40	937·50	377·74	391·14	....
	Wiluna	....	....	....	....	....	....						
	Black Range	....	....	47·75	122·84	122·84	....						
Murchison	Cue	7·45	....	....	163·39	170·84	8·13	12·28	13·32	129,229·30	32,925·64	32,951·24	2,488·85
	Meekatharra	1·38	2·15	1,664·00	200·85	204·38	....						
	Day Dawn	....	....	114·50	6·42	6·42	....						
	Mt. Magnet	3·45	11·17	127,450·80	32,554·98	32,569·60	2,480·72						
Yalgoo	....	....	....	....	....	....	....	....	30·11	657·00	190·79	220·90	....
Mt. Margaret	Mt. Morgans	....	....	12·00	3·13	3·13	....	·30	27·04	1,501·75	1,254·93	1,282·27	2·19
	Mt. Malcolm	·30	27·04	1,489·75	1,251·80	1,279·14	2·19						
	Mt. Margaret	....	....	....	....	....	....						
North Coolgardie	Menzies	....	7·62	966·50	203·91	211·53	....	·27	7·62	2,022·00	409·30	417·19	....
	Ularring	....	....	672·75	134·99	134·99	....						
	Niagara	....	....	15·75	4·40	4·40	....						
	Yerilla	·27	....	367·00	66·00	66·27	....						
Broad Arrow	....	....	....	....	....	....	....	....	9·75	1,030·50	891·19	900·94	·32
North-East Coolgardie	Kanowna	....	....	2,433·00	463·43	463·43	....	·17	....	2,466·75	464·75	464·92	....
	Kurnalpi	·17	....	33·75	1·32	1·49	....						
East Coolgardie	East Coolgardie	4·87	13·60	1,983,145·75	389,522·54	389,541·01	107,174·01	4·89	13·60	1,983,181·25	389,553·47	389,571·96	107,174·01
	Bulong	·02	....	35·50	30·93	30·95	....						
Coolgardie	Coolgardie	3·80	99·13	4,393·50	994·00	1,096·93	....	3·80	146·96	4,697·25	1,047·93	1,198·69	....
	Kunanalling	....	47·83	303·75	53·93	101·76	....						
Yilgarn	....	....	....	....	....	....	....	....	14·28	1,764·00	1,103·76	1,118·04	1,837·94
Dundas	....	....	....	....	....	....	....	....	....	177,348·50	84,094·73	84,094·73	71,970·94
Phillips River	....	....	....	....	....	....	....	....	....	480·00	1,218·07	1,218·07	3,805·61
South-West Mineral Field	....	....	....	....	....	....	....	....	....	....	....	....	....
Northampton Mineral Field	....	....	....	....	....	....	....	....	....	....	....	....	....
State Generally	....	....	....	....	....	....	....	....	....	....	....	....	....
Outside Proclaimed Goldfield	....	....	....	....	....	....	....	....	....	....	....	....	....
Total	....	....	....	....	....	....	....	**21·71**	**289·12**	**2,307,737·30**	**515,639·22**	**515,950·05**	**187,360·18**

TABLE III.

Return showing total production reported to the Mines Department, and respective Districts and Goldfields from whence derived, to 31st December, 1968.

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.
West Kimberley	....	....	....	....	....	....	....	1·30	24·68	1·00	2·49	28·47	37,317·55
Kimberley	....	....	....	....	....	....	....	9,086·26	3,035·43	22,931·90	17,292·01	29,413·70	128·76
West Pilbara	....	....	....	....	....	....	....	6,339·37	374·74	24,900·96	24,317·02	31,031·13	1,910·66
Pilbara	Marble Bar	15,511·22	4,572·17	347,889·27	335,351·71	355,435·10	33,276·30	26,020·75	7,481·86	498,127·94	470,855·16	504,357·77	34,357·22
	Nullagine	10,509·53	2,909·69	150,238·67	135,503·45	148,922·67	1,080·92						
Ashburton	....	....	....	....	....	....	....	9,268·52	482·46	6,807·10	2,913·43	12,664·41	41,971·38
Gascoyne	....	....	....	....	....	....	....	698·49	121·33	2,507·75	3,988·79	4,808·61	87·17
Peak Hill	....	....	....	....	....	....	....	3,387·79	5,398·30	783,070·73	322,738·34	331,524·43	3,794·07
East Murchison	Lawlers	7,103·51	2,362·05	2,022,257·42	827,733·59	837,199·15	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	22,226·13	12,628,060·33	3,655,590·29	3,686,827·37	60,324·41
	Black Range	1,670·96	18,609·97	1,732,153·22	955,536·73	975,817·66	22,733·32						
Murchison	Cue	5,145·34	9,109·73	6,815,612·31	1,403,540·20	1,417,795·27	274,843·78						
	Meekatharra	14,705·91	18,718·28	2,326,061·57	1,311,629·38	1,345,053·57	5,278·85	25,788·75	59,648·73	15,154,128·43	5,972,843·50	6,058,280·98	518,372·45
	Day Dawn	3,291·61	11,341·80	2,037,710·13	1,375,648·23	1,390,281·64	169,447·42						
	Mt. Magnet	2,645·89	20,478·92	3,974,744·42	1,882,025·69	1,905,150·50	68,802·40						
Yalgoo	....	....	....	....	....	....	....	1,815·77	3,254·11	444,763·58	264,362·31	269,432·19	1,523·06
Mt. Margaret	Mt. Morgans	3,574·87	9,401·98	1,218,151·31	718,014·68	730,991·53	5,831·33						
	Mt. Malcolm	4,067·66	16,696·03	7,756,125·72	3,072,767·32	3,093,531·01	190,796·46	11,790·63	35,452·36	11,502,450·27	4,964,825·56	5,012,068·55	262,818·49
	Mt. Margaret	4,148·10	9,354·35	2,528,173·24	1,174,043·56	1,187,546·01	66,190·70						
North Coolgardie	Menzies	1,696·69	7,039·71	1,953,577·23	1,433,905·72	1,442,642·12	39,176·43						
	Ularring	129·66	7,298·59	538,441·70	447,401·40	454,829·65	22,286·97	4,857·64	19,977·19	3,733,790·73	2,588,382·43	2,613,217·26	72,525·81
	Niagara	1,718·48	1,821·77	944,525·02	528,605·23	532,145·48	5,716·17						
	Yerilla	1,312·81	3,817·12	297,246·78	178,470·08	183,600·01	5,346·24						
Broad Arrow	....	....	....	....	....	....	....	21,998·52	28,016·86	1,414,291·74	753,986·77	804,002·15	5,703·32
North-East Coolgardie	Kanowna	106,549·25	13,635·61	1,013,695·61	628,853·44	749,038·30	3,049·28	119,386·69	21,942·62	1,028,486·93	648,084·21	789,413·52	3,061·99
	Kurnalpi	12,837·44	8,307·01	14,791·32	19,230·77	40,375·22	12·71						
East Coolgardie	East Coolgardie	33,741·38	41,230·91	94,249,403·24	37,774,571·34	37,849,543·63	6,287,386·41	61,146·91	57,267·68	94,437,992·82	37,907,749·35	38,026,163·94	6,287,486·17
	Bulong	27,405·53	16,036·77	188,589·58	133,178·01	176,620·31	99·76						
Coolgardie	Coolgardie	17,212·71	21,925·00	3,009,275·97	1,546,960·51	1,586,098·22	54,478·97	18,734·60	27,796·39	3,376,383·17	1,800,797·20	1,847,328·19	55,252·03
	Kunanalling	1,521·89	5,871·39	367,107·20	253,836·69	261,229·97	773·06						
Yilgarn	....	....	....	....	....	....	....	2,198·76	6,347·71	8,287,751·37	2,440,813·47	2,449,359·94	215,732·74
Dundas	....	....	....	....	....	....	....	2,256·21	16,400·63	6,558,350·62	3,094,663·01	3,113,319·85	1,846,911·92
Phillips River	....	....	....	....	....	....	....	607·11	823·32	131,139·24	123,226·72	124,657·15	74,608·63
South-West Mineral Field	....	....	....	....	....	....	....	313·08	48·66	4,747·83	2,436·72	2,798·46	15·18
Northampton Mineral Field	....	....	....	....	....	....	....	....	....	....	....	....	5,185·58
State Generally	....	....	....	....	....	....	....	1,195·07	1,111·85	27·00	10,068·96	12,375·88	32,662·66
Outside Proclaimed Goldfield	....	....	....	....	....	....	....	....	....	....	....	....	1,259·58
Total	....	....	....	....	....	....	....	**335,903·17**	**317,238·04**	**160,040,711·44**	**65,069,937·74**	**65,723,073·95**	**9,563,010·83**

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	923,686·96	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	1,697,553·59	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	651,338·35	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	540,067·08	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	698,366·29	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	4,091·51	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
1967	2,743·28	573,277·73	576,021·01	18,071,924
1968	918·86	510,784·17	511,703·03	16,785,723
	11,602,361·23	55,653,117·97	67,255,479·20	$1,064,309,844

	1967	1968
	$A	$A
Estimated Mint value of above production	1,039,398,152	1,055,388,911
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	2,946,765	3,741,729
Estimated Total	$A1,047,524,121	$A1,064,309,844
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	19,732,841	22,353,890
Gross estimated value of gold won	$A1,067,579,858	$A1,086,986,630

TABLE V.

Quantity and Value of Minerals, other than Gold, Reported during the year, 1968

Number of Lease, Claim or Area	Goldfield or Mineral Field	Registered Name of Producer	Quantity Long Tons	Metallic Content		Value $A
		ASBESTOS (Chrysotile)				
L.T.T. 1454	Pilbara	Hancock, R. G.	67·00	....	(b)	2,814·00
		BARYTES				
M.C. 20N	Murchison	Universal Milling Co. Pty. Ltd.	655·66	....	(a)	9,967·50
		BAUXITE				
M.L. 1.S.A.	South West	Western Aluminium N.L.	1,607,988·10	....		N.A.
		BERYL (g) (h)				
M.L. 80 etc.	Coolgardie	Australian Glass Manufacturers Co.	10·45	122·25	(b)	4,890·00
	Gascoyne	Sundry Producers—Crown Land	2·95	30·68	(b)	777·59
			13·40	152·93	(b)	5,667·59
		BUILDING STONE (Quartz)				
M.L. 80 etc.	Coolgardie	Australian Glass Manufacturers Co.	36·00	....	(b)	838·00
		BUILDING STONE (Quartz Dead White)				
M.C. 3S	Coolgardie	Erceg C. & Party	350·23	....		7,856·00
P.A. 1790S	Coolgardie	Erceg C. & Party	45·00	....		1,080·00
			395·23	....	(a)	8,936·00
		BUILDING STONE (Quartzite)				
M.C. 1158H etc.	South West	House, R. P.	1,318·00	....	(c)	5,260·00
		BUILDING STONE (Sandstone)				
M.C. 1036H	South West	Caporn, C. A.	8·00	....		48·00
M.C. 990H	South West	Caporn, C. A.	9·00	....		54·00
			17·00	....	(a)	102·00
		BUILDING STONE (Spongolite)				
M.C. 1062H	South West	Worth, H.	148·00	....		1,776·00
Q.A.I. etc.	Phillips River	Frayne, W. L.	37·00	....		481·00
			185·00	....	(c)	2,257·00
		BUILDING STONE (Tripolite)				
M.C. 753H etc.	South West	Gerodetti, P.	260·00	....	(c)	260·00
		CLAYS (Bentonite)				
M.C. 1042H etc.	South West	Noonan, E. J.	37·70	....	(a)	301·60
		CLAYS (Cement Clay)				
M.C. 1019H etc.	South West	Bell Bros. Pty. Ltd.	1,358·00	....		1,466·64
M.C. 788H	South West	Bell Bros. Pty. Ltd.	16,470·00	....		46,115·40
M.C. 1018H	South West	Swan Portland Cement Ltd.	4,777·38	....		4,438·85
			22,605·38	....	(c)	52,020·89
		CLAYS (Fireclay)				
M.C. 304H	South West	Clackline Refractories Ltd.	2,263·00	....		4,526·00
M.C. 522H etc.	South West	Bridge, J. S. & T. D.	48,820·00	....		48,820·00
M.C. 732H etc.	South West	Midland Brick Co. Pty. Ltd.	4,434·00	....		2,815·00
M.C. 685H	South West	Kargotich, T. J. P. & S.	1,750·00	....		1,750·00
M.C. 1114H	South West	Midland Brick Co. Pty. Ltd.	33,486·00	....		16,743·00
Private Property	South West	Unspecified Producers	13,246·35	....		6,471·30
			103,999·35	....	(c)	81,125·30
		CLAYS (White Clay-Ball Clay)				
M.C. 109H	South West	Brisbane and Wunderlich Ltd.	949·00	....	(c)	7,592·00

TABLE V.—*Quantity and Value of Minerals, other than Gold, Reported during the Year 1968—continued*

Number of Lease, Claim or Area	Goldfield or Mineral Field	Registered Name of Producer	Quantity Long Tons	Metallic Content	Value $A
		CLAYS (*Brick Pipe and Tile Clay)			
Private Property	South West	Stoneware Pipes & Tiles Pty. Ltd.	2,484·00	....	6,706·80
Private Property	South West	Stoneware Pipes & Tiles Pty. Ltd.	9,952·00	....	19,904·00
Private Property	South West	Stoneware Pipes & Tiles Pty. Ltd.	3,722·00	....	7,444·00
Private Property	South West	Swaby, F. W.	25,000·00	....	62,500·00
Private Property	South West	†Unspecified Producers	5,032·70	....	2,669·15
			46,190·70	....	(c) 99,223·95

* 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.	605,160·15	....	1,973,185·04
C.M.L. 437 etc.	Collie	Western Collieries Ltd.	482,218·90	....	2,843,540·20
			1,087,379·05	....	(e) 4,816,725·24
		COBALT (Metallic By-Product Nickel Mining) (h)			
M.C. 150 etc.	Coolgardie	Western Mining Corporation Ltd.	....	Cobalt Tons 91·37	N.A.
		COPPER (Metallic By-Product Nickel Mining) (h)			
M.C. 150 etc.	Coolgardie	Western Mining Corporation Ltd.	....	Copper Tons 730·21	N.A.
		COPPER ORE AND CONCENTRATES (g) (h)			
M.C. 35 etc.	Phillips River	Ravensthorpe Copper Mines N.L.	4,275·58	Copper Units 96,310·00	(b) 900,452·36
		Gold and Silver Content transferred to respective Items	Gold	Fine Ounces 1,382·76	43,338·20
			Silver	4,584·69	8,241·66
		CUPREOUS ORE AND CONCENTRATES (Fertiliser)		Assay Cu %	
M.C. 39	Yalgoo	Shearer, R. W.	251·50	10·00	17,605·00
M.C. 43P	Peak Hill	Parkinson, T. L.	72·36	11·18	5,913·10
M.C. 97P	Peak Hill	Alac, M.	116·55	21·22	15,859·17
M.C. 382L	Pilbara	McPherson, K. J.	45·54	14·64	5,304·02
M.L. 259	West Pilbara	Lee, T.	145·90	9·49	5,121·89
M.L. 262	West Pilbara	Lee, T.	8·93	10·25	329·88
M.L. 1.O.P.	Outside Proclaimed	T. Simms (Western Mining Corp.)	49·05	19·00	1,098·13
			689·83	13·08	(a)(b) 51,231·19
		DIATOMACEOUS EARTH (Calcined)			
M.C. 982H	South West	Universal Milling Co. Pty. Ltd.	43·50	....	(c) 1,362·00
		FELSPAR			
M.L. 80 etc.	Coolgardie	Australian Glass Manufacturers Co.	469·00	....	(a) 7,035·00
		GLASS SAND			
M.C. 417H	South West	Australian Glass Manufacturers Co.	13,024·00	....	17,581·00
M.C. 1017H	South West	Ready Mix Concrete (W.A.) Pty. Ltd.	6,214·00	....	N.A.
M.C. 1191H	South West	Silicon Quarries Pty Ltd.	1,000·00	....	N.A.
M.C. 285H	South West	Leach, R. J.	322·00	....	966·00
			20,560·00	....	(c) 18,547·00
		GYPSUM			
M.C. 30, etc.	Yilgarn	Ajax Plaster Co. Pty. Ltd.	17,933·00	....	32,284·80
M.C. 51, etc.	Yilgarn	H. B. Brady Co. Pty. Ltd.	11,831·00	....	29,577·50
M.C. 9, etc.	Yilgarn	West Australian Plaster Mills	19,915·00	....	36,027·00
M.C. 43, etc.	Gascoyne	Garrick Agnew Pty. Ltd.	51,015·00	....	200,000·00
M.C. 12, etc.	Dundas	McDonald & Whitfield	150·00	....	150·00
M.C. 612H, etc.	South-West	†Gypsum Industries of Aust. Pty. Ltd.	2,562·00	....	4,564·00
M.C. 485H, etc.	South-West	Swan Portland Cement	1,563·37	....	3,066·55
M.C. 1115H	South-West	†McAndrew, R. W.	50·00	....	95·00
			105,019·37	....	(a)(b)305,764·85

† For Agricultural purposes.
Plaster of paris reported as manufactured during the year being 27,694 tons from 39,327 tons of Gypsum by five Companies. Gypsum used in the manufacture of Cement = 12,406·37 tons.

TABLE V.—*Quantity and Value of Minerals, other than Gold, Reported during the Year 1968—continued*

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)			
			Ore Treated Tons	Pig Iron Recovered Tons	
T.R. 1258H	Yilgarn	Charcoal Iron Steel Industry	92,400·00	57,888·00 Av. Assay 62% Fe	3,189,393·00 (c) (d)
		IRON ORE (*Ore Railed to Kwinana)			
				Av. Assay Fe %	
M.L. 2 S.A.	Yilgarn	Dampier Mining Co. Ltd.	*1,231,194·00	60·82	(n) 2,437,767·00
		* Includes 669,763 W.L. Tons exported from Kwinana to Eastern States.			
		IRON ORE (Ore Exported to Eastern States)			
M.L. 10, etc.	West Kimberley	Dampier Mining Co. Ltd.	1,364,725·00	63·99	(n) 5,299,977·00
M.L. 50, etc.	West Kimberley	Dampier Mining Co. Ltd.	1,322,134·00	65·60	
			2,686,859·00	....	(n) 5,299,977·00
		IRON ORE (Ore Exported Overseas)			
M.L. 50, etc.	West Kimberley	Dampier Mining Co. Ltd.	91,412·00	67·02	697,516·05
235 S.A.	Pilbara	Goldsworthy Mining Pty. Ltd.	4,395,114·08	65·02	37,106,369·61
4 S.A.	West Pilbara	Hamersley Iron Pty. Ltd.	7,211,560·13	65·14	60,353,811·32
M.C. 878H, etc.	South-West	Western Mining Corp. Ltd.	634,092·14	60·38	5,094,193·00
			12,332,178·35	....	103,251,889·98 (b)
		IRON ORE—PELLETS (Exported Overseas)			
4 S.A.	West Pilbara	Hamersley Iron Pty. Ltd.	927,793·31	64·33	(b) 9,750,970·12
		LEAD ORES AND CONCENTRATES (g) (h)			
				Lead Tons	
M.C. 47	Northampton	Camp and Party	28·34	20·81	2,644·18
M.L. 284	Northampton	Nooka Lead Mine	*97·76	65·33	7,796·93
M.C. 76	Northampton	Mitchell, G. H. & J. M.	35·75	20·17	2,297·13
M.L. 234	Northampton	Mary Springs Lead Mine	255·78	204·71	27,246·85
			417·63	311·02	(b) 39,985·09
		* Contained Silver—45·66 fine ozs.—$91·57. Silver content transferred to Silver Item.			
		* LIMESTONE (for Building and Burning Purposes, etc.)			
M.C. 1241H	South-West	Bellombra, M. & L.	1,795·00	....	5,026·00
M.C. 874H	South-West	Brambles Holdings Ltd.	19,848·00	....	3,969·60
M.C. 1290H	South-West	Caroleo, R. D. & Bellombra, V.	6,593·00	....	19,119·70
M.C. 1227H	South-West	Korsunski, G.	102,041·00	....	20,408·20
M.C. 1071H	South-West	Koot, J. M.	18,984·00	....	26,872·00
M.C. 1093H	South-West	Multari, N.	342·00	....	1,830·00
M.C. 1105H	South-West	Moore, F. W. & E. M. Pty. Ltd.	1,442·00	....	2,884·00
M.C. 1660H	South-West	Swan Portland Cement	30,580·45	....	38,454·07
M.C. 702H, etc.	South-West	Makrides, J.	60·00	....	120·00
M.C. 1284H	South-West	Panizza, P.	17,948·00	....	31,993·80
Lot M1405	South-West	Parham Grazing Co.	8,235·00	....	21,087·50
M.C. 532H	South-West	Swan Portland Cement	180·00	....	306·00
M.C. 727H	South-West	Thiess Bros. Pty. Ltd.	72,567·00	....	21,770·10
M.C. 709H	South-West	Snader, R.	3,876·00	....	775·20
Private Property	South-West	Unspecified Producers	677,112·00	....	725,647·00
			961,603·45	....	(c) 920,263·17
		* LIMESTONE (For Agricultural Purposes)			
M.C. 50	Dundas	Esperance Lime Supply	102·00	....	1,071·00
M.C. 1322H	South-West	Lance, T. J.	1,933·00	....	1,933·00
M.C. 732H	South-West	Plozza, C. W. & W. A.	300·00	....	600·00
M.C. 1220H	South-West	Steer, E. J.	161·00	....	644·00
			2,496·00	....	(c) 4,248·00
		* Incomplete.			
		LITHIUM ORES (Petalite) (h)			
				Li20 Units	
M.L. 80, etc.	Coolgardie	Australian Glass Manufacturers Co.	738·00	3,111·60	(a) 11,730·70
		MAGNESITE			
M.C. 76, etc.	Phillips River	Norseman Gold Mines N.L.	166·36	....	(a) 2,411·50

TABLE V.—*Quantity and Value of Minerals, other than Gold, Reported during the Year 1968—continued*

Number of Lease, Claim or Area	Goldfield or Mineral Field	Registered Name of Producer	Quantity Long Tons	Metallic Content	Value $A
		MANGANESE (Metallurgical Grade) (*g*)			
				Av. Assay Mn %	
M.C. 268, etc.	Pilbara	Mt. Sydney Manganese Pty. Ltd.	65,351·06	50·17	1,480,768·20
M.C. 244L, etc.	Pilbara	Westralian Ores Pty. Ltd.	52,382·00	51·21	1,169,088·00
M.C. 24P, etc.	Peak Hill	Westralian Ores Pty. Ltd.	27,723·00	36·23	433,284·00
			145,456·06	47·89	(*b*) 3,083,140·20
		MINERAL BEACH SANDS (Ilmenite) (*g*)			
				Av. Assay TiO2 %	
Sussex Loc. 7	South-West	Cable (1956) Ltd.	21,962·71	54·47	N.A.
M.C. 746H	South-West	Ilmenite Minerals Pty. Ltd.	47,603·59	54·54	N.A.
M.C. 398H, etc.	South-West	Western Mineral Sands Pty. Ltd.	122,726·50	54·00	N.A.
M.C. 619H, etc.	South-West	Westralian Sands Ltd.	56,609·71	57·76	N.A.
M.C. 516H, etc.	South-West	Western Titanium N.L.	215,484·32	54·46	N.A.
			464,386·83	54·75	(*b*) 4,559,736·18
		MINERAL BEACH SANDS (Monazite) (*g*) (*h*)			
				Tho2 Units	
M.C. 619H, etc.	South-West	Westralian Sands Ltd.	703·25	4,571·13	99,213·00
M.C. 516H, etc.	South-West	Western Titanium N.L.	1,052·06	6,869·98	134,489·91
M.C. 746H, etc.	South-West	Ilmenite Mineral Pty. Ltd.	40·00	264·00	5,600·00
Sussex Loc. 7	South-West	Cable (1956) Pty. Ltd.	40·00	263·60	5,600·00
			1,835·31	11,968·71	(*b*) 244,902·91
		MINERAL BEACH SANDS (Rutile) (*g*) (*h*)			
				TiO2 Tons	
M.C. 516H, etc.	South-West	Western Titanium N.L.	845·43	813·74	(*b*) 66,754·30
		MINERAL BEACH SANDS (Leucoxene) (*g*) (*h*)			
				TiO2 Tons	
M.C. 619H, etc.	South-West	Westralian Sands Ltd.	686·70	618·03	30,903·00
M.C. 516H, etc.	South-West	Western Titanium N.L.	919·92	827·58	44,683·42
M.C. 746H, etc.	South-West	Ilmenite Minerals Pty. Ltd.	88·79	80·19	4,519·13
			1,695·41	1,525·80	(*b*) 80,105·55
		MINERAL BEACH SANDS (Zircon) (*g*) (*h*)			
				ZrO2 Tons	
M.C. 619H, etc.	South-West	Westralian Sands Ltd.	10,217·40	6,635·15	361,486·00
M.C. 516H, etc.	South-West	Western Titanium N.L.	17,216·32	11,332·23	500,565·49
M.C. 746H, etc.	South-West	Ilmenite Minerals Pty. Ltd.	646·35	419·27	26,667·95
Sussex Loc. 7	South-West	Cable (1956) Ltd.	292·00	191·42	10,659·00
			28,372·07	18,578·07	(*b*) 899,378·44
		MINERAL BEACH SANDS (Xenotime) (*g*)			
				Y203 Lbs.	
M.C. 516H, etc.	South-West	Western Titanium N.L.	2·00	858·49	(*b*) 4,946·23
		NICKEL CONCENTRATES (*i*)			
				Av. Assay Ni %	
M.C. 150, etc.	Coolgardie	Western Mining Corp. Ltd.	45,272·82	N.A.	(*o*)10,128,936·00
		OCHRE RED			
M.C. 26	Murchison	Universal Milling Co. Pty. Ltd.	515·05	....	(*a*) 9,823·50
		PETALITE—see Lithium Ores			
		PETROLEUM (Crude Oil)			
			bbls.		
1H	Ashburton	West Australian Petroleum Pty. Ltd.	10,641,703·00	....	34,015,442·00 (*m*)
		PYRITES ORES AND CONCENTRATES (for Sulphur)			
				Sulphur Content Tons	
G.M.L. 5715E, etc.	East Coolgardie (*i*) (*j*)	Gold Mines of Kalgoorlie (Aust.) Ltd.	17,333·40	7,400·09	185,001·60
G.M.L. 1460, etc.	Dundas (*i*)	Norseman Gold Mines N.L.	15,546·00	7,032·98	235,823·00
			32,879·40	14,433·07	(*a*) 420,824·60

TABLE V.—*Quantity and Value of Minerals, other than Gold, Reported during the Year 1968—continued*

Number of Lease, Claim or Area	Goldfield or Mineral Field	Registered Name of Producer	Quantity Long Tons	Metallic Content	Value $A
		SEMI PRECIOUS STONES (Amethyst)			
			lbs.		
M.C. 65	Ashburton	Soklich, F. F. D. & Z.	17,534·00	....	7,172·60
		SEMI PRECIOUS STONES (Chalcedony)			
M.C. 60	Dundas	Rose, F. G.	13,440·00	....	600·00
P.A. 5741W	Broad Arrow	W.A. Lapidary and Rock Hunting Hunting Club Inc.	2,200·00	....	2,000·00
			15,640·00	....	2,600·00
		SEMI PRECIOUS STONES (Emeralds)			
			Carats		
M.C. 65	Murchison	Cook, C. S.	418·00	....	798·00
		SILVER			
			Fine Oz.		
		By-Product Gold Mining	223,022·81	....	455,399·36
		By-Product Copper Mining	4,584·69	....	8,241·66
		By-Product Lead Mining	45·66	....	91·57
			227,653·16	....	463,732·59
		TALC			
Private Property	South-West	Three Springs Talc Pty. Ltd.	24,724·07	....	(b)(c)467,705·70
		TANTO/COLUMBITE ORES AND CONCENTRATES (g) (h)			
				Ta205 Units	
M.L. 660, etc.	Greenbushes (k)	Greenbushes Tin N.L.	35·29	1,735·12	253,275·23
M.C. 647, etc.	Greenbushes (k)	Vultan Syndicate	45·61	386·95	51,669·22
M.L. 707H	Greenbushes	Guest, E. G.	·49	20·37	2,781·75
	Pilbara	Crown Land	·21	11·50	2,271·60
	Pilbara	Crown Land—District Generally	·70	15·61	3,093·41
D.C. 732	Pilbara	McLeod, D. W.	2·79	86·62	15,098·61
D.C. 53, etc.	Pilbara	Cooglegong Tin Pty. Ltd.	*393·36	940·20	29,112·17
D.C. 195, etc.	Pilbara	Pilbara Tin Pty. Ltd.	·67	16·92	3,910·00
D.C. 281, etc.	Pilbara	J. A. Johnston & Sons Pty. Ltd.	14·20	142·64	4,292·18
			493·32	3,355·93	(b) 365,504·17

* Includes 387·01 tons low Grade (Rejects) valued at $25,390·29.

Number of Lease, Claim or Area	Goldfield or Mineral Field	Registered Name of Producer	Quantity Long Tons	Metallic Content	Value $A
		TIN CONCENTRATES (g) (h)			
				Tons	
D.C. 53, etc.	Pilbara	Cooglegong Tin Pty. Ltd.	*542·67	116·99	311,173·31
D.C. 201, etc.	Pilbara	Pilbara Tin Pty. Ltd.	501·41	365·12	1,030,750·46
D.C. 281, etc.	Pilbara	Johnston, J. A. & Sons Pty. Ltd.	147·14	94·00	259,455·20
D.C. 732	Pilbara	McLeod, D. W.	3·93	2·42	5,955·31
D.C. 481, etc.	Pilbara	S. H. Stubbs	15·02	9·85	25,263·85
M.C.S. 691, etc.	Pilbara	Edwards, M. R.	4·86	3·01	7,430·03
D.C. 535	Pilbara	Edwards, J. M. & M. A.	2·14	1·34	5,857·00
	Pilbara	Sundry Persons—Crown Lands	·25	·18	481·42
	Pilbara	Crown Lands—District Generally....	16·15	11·49	29,989·66
M.C. 93	Dundas	Weston, B. T.	·22	·14	379·93
M.L. 707	Greenbushes	E. A. Guest	7·87	5·37	13,295·37
M.L. 660, etc.	Greenbushes	Greenbushes Tin N.L.	268·63	188·08	546,973·21
M.L. 647, etc.	Greenbushes	Vultan Syndicate	52·43	30·75	72,688·41
	Murchison	Sundry Persons—Crown Land	·06	·04	95·25
			1,562·78	828·78	(b) 2,309,788·41

* Includes 387·01 tons Low Grade (Rejects) valued at $20,519·81.

Number of Lease, Claim or Area	Goldfield or Mineral Field	Registered Name of Producer	Quantity Long Tons	Metallic Content	Value $A
		TUNGSTEN ORE AND CONCENTRATES (Wolfram)			
				W03 Units	
P.A. 352 W.P.	West Pilbara	Glasson, A. E.	·61	34·40	(b) 603·46

REFERENCES

N.A.—Not available for publication.

(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 realised 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. (m) Value based on the price of $U.S. 3·58 per barrel as assessed by the Tariff Board for Barrow Island crude oil at Kwinana. (n) Nominal value ex mine. (o) Estimated nominal F.O.B. value based on the price of Nickel Cathodes as published from time to time in the publication "Metals Week".

NOTE.—If utilised for publication please acknowledge release from the Hon. Minister for Mines.

TABLE VI—TOTAL MINERAL OUTPUT OF WESTERN AUSTRALIA

Recorded mineral production of the State to 31st December, 1968, 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)	,,	914,569·00	54,874,140.00
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	,,	111,007·98	986,146.60
Chrocidolite	,,	152,466·74	33,496,644.98
Tremolite	,,	1·00	50.00
Barytes	,,	7,217·07	103,365.20
Bauxite (Crude Ore) (*g*)	,,	36,741·00	187,069.50
Beryl	,,	3,656·41	949,552.44
Bismuth	lb.	12,479·70	7,628.60
Building Stone (*g*)—			
Chrysotile—Serpentine	tons	4·45	106.00
Granite (Facing Stone)	,,	344·00	15,488.00
Lepidolite	,,	8·35	146.00
Prase	,,	9·50	275.00
Quartz (Dead White)	,,	1,137·23	22,518.00
Quartz	,,	243·23	5,293.00
Quartzite	,,	3,916·00	15,844.00
Sandstone	,,	600·00	3,600.00
Sandstone (Donnybrook)	,,	83·00	3,486.00
Slate	,,	235·00	2,115.00
Spongolite	,,	3,100·00	32,624.00
Tripolite	,,	260·00	260.00
Calcite	,,	5·00	50.00
Chromite	,,	14,419·05	416,593.50
Clays—			
Bentonite	,,	11,684·33	74,778.52
Brick, Pipe and Tile Clays (*g*)	,,	483,112·70	825,363.90
Cement Clays	,,	351,663·43	624,356.73
Fireclay	,,	633,778·16	1,018,194.36
Fullers Earth	,,	459·40	3,821.00
White Clay—			
Ball Clay	,,	25,891·60	162,472.60
Kaolin	,,	5,963·07	22,122.61
Coal	,,	38,055,674·19	121,235,204.68
Cobalt (Metallic By-Product Nickel Mining)	,,	91·37	N.A.
Copper (Metallic By-Product) (*a*) (*i*)	,,	191·50	65,375.10
Copper (Metallic By-Product Nickel Mining)	,,	730·21	N.A.
Copper Ore and Concentrates	,,	299,801·03	8,998,819.89
Corundum	,,	63·15	1,310.00
Cupreous Ore and Concentrates (Fertiliser)	,,	84,960·12	3,049,563.44
Diamonds	,,	(e)	48.00
Diatomaceous Earth (Calcined)	,,	520·00	15,991.00
Dolomite	,,	3,046·82	26,118.20
Emeralds (cut and rough)	carats	18,799·68	4,642.00
Emery	tons	21·15	750.00
Felspar	,,	69,867·61	513,215.06
Fergusonite	,,	0·30	782.80
Gadolinite	,,	1·00	224.00
Glass Sand	,,	216,565·61	(*g*) 235,259.12
Glauconite	,,	(*h*) 6,467·00	(*f*) 300,769.00
Gold (Mint and Export)	fine ozs.	67,255,479·20	1,064,309,844.00
Graphite	tons	153·20	2,608.40
Gypsum	,,	1,099,251·70	2,412,623.98
Iron Ore—			
Pig Iron Recovered	,,	605,450·08	27,886,127.12
Ore Exported	,,	40,879,813·14	217,578,094.04
Pellets Exported	,,	927,793·31	9,750,970.12
For Flux	,,	58,064·35	74,096.00
Locally used Ore	,,	1,718,967·00	3,403,558.00
Jarosite	,,	9·54	75.00
Kyanite	,,	4,215·69	43,562.00
Lead Ores and Concentrates	,,	480,240·12	10,391,914.08
Limestone (*g*)	,,	3,069,391·16	3,311,529.36
Lithium Ores—			
Petalite	,,	3,513·98	54,124.80
Spodumene	,,	106·58	3,627.20
Magnesite	,,	28,585·64	302,472.86
Manganese—			
Metallurgical Grade	,,	1,241,582·90	29,454,804.26
Battery Grade	,,	2,218·25	90,860.20
Low Grade	,,	5,054·36	81,538.20
Mica	,,	32,930·00	7,968.48

TABLE VI.—Total Mineral Output of Western Australia—*continued*

Mineral		Quantity	Value
			$A
Mineral Beach Sands—			
Ilmenite Concentrates	tons	2,870,291·51	27,668,879.67
Monazite Concentrates	,,	10,887·99	1,085,989.23
Rutile	,,	5,824·29	351,564.02
Leucoxene	,,	6,053·75	239,587.09
Zircon	,,	155,933·18	4,523,955.21
Xenotime	,,	2·00	4,946.23
Crude Concentrates (Mixed)	,,	155·95	1,553.00
Molybdenite	,,	51·00	1,010.00
Nickel	,,	47,525·74	10,510,564.00
Ochre—			
Red	,,	10,363·99	219,993.90
Yellow	,,	447·60	5,955.50
Petroleum (Crude Oil)	bbls.	15,288,641·00	48,869,047.00
Phosphatic Guano	tons	11,857·06	145,420.90
Pyrites Ore and Concentrates (For Sulphur) (*b*)	,,	1,333,631·91	16,087,808.13
Quartz Grit	,,	829·50	1,400.70
Semi-Precious Stones—			
Amethyst	lb.	22,596·40	12,464.94
Beryl (Coloured)	,,	200·00	100.00
Chalcedony	,,	51,480·00	5,150.00
Chrysoprase	,,	22,853·00	1,010.00
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.	11,964,418·95	6,402,634.14
Soapstone	tons	565·40	3,855.70
Talc	,,	100,059·13	2,521,167.74
Tanto/Columbite Ores and Concentrates	,,	1,077·78	1,677,938.10
Tin	,,	25,431·59	16,080,635.43
Tungsten Ores and Concentrates—			
Scheelite	,,	169·18	143,424.24
Wolfram	,,	304·96	125,810.16
Vermiculite	,,	1,832·96	23,661.20
Zinc (Metallic By-Product) (*d*)	,,	2,887·75	(*j*)
Zinc Ore (Fertiliser)	,,	20·00	200.00
Total Value to 31st December, 1968		$A	1,736,603,312.02

(*a*) By-Product from Gold Mining.
(*b*) Part By-Product from Gold Mining.
(*c*) By-Product from Copper and Lead Mining.
(*d*) By-Product from Lead Mining.
(*e*) Quantity not recorded.
(*f*) Value of mineral or concentrate recovered.
(*g*) Incomplete.
(*h*) Mineral Recovered.
(*i*) Assayed Metallic Content.
(*j*) Value included in Lead Value.
(*k*) Based on the price assessed by the Tariff Board for Barrow Island crude oil at Kwinana, i.e. $US3·58 per bbl. ($A3·196428).

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 below ground in the larger mining companies operating in Western Australia during 1967 and 1968.†

Company	1967			1968		
	Above	Under	Total	Above	Under	Total
Gold*—						
Central Norseman Gold Corporation N.L.	137	147	284	130	141	271
Gold Mines of Kalgoorlie (Aust.) Ltd. (Boulder)	369	315	684	334	231	565
Great Boulder G.M.s Ltd.	249	293	542	200	198	398
Hill 50 Gold Mine N.L.	94	108	202	93	99	192
Lake View & Star Ltd.	348	484	832	352	450	802
Gold Mines of Kalgoorlie (Aust.) Ltd. (Mt. Charlotte)	8	113	121	9	115	124
North Kalgurli (1912) Ltd.	201	256	457	193	250	443
All other operators	633	272	905	555	217	772
State Average	2,039	1,988	4,027	1,866	1,701	3,567
Alumina (from Bauxite)—						
Western Aluminium N.L.	526	....	526	724	....	724
Coal—						
Griffin Coal Mining Co. Ltd.	185	....	185	180	....	180
Western Collieries Ltd.	99	410	509	91	378	469
Copper—						
Ravensthorpe Copper Mines N.L.	48	45	93	53	58	111
Iron Ore—						
Charcoal Iron & Steel	7	....	7	7	....	7
Dampier Mining Co. Ltd.	437	....	437	460	....	460
Goldsworthy Mining Ltd.	145	....	145	321	....	321
Hamersley Iron Pty. Ltd.	506	....	506	418	....	418
Western Mining Corporation	90	....	90	89	....	89
Mineral Beach Sands—						
Cable (1956) Ltd.	26	....	26	14	....	14
Ilmenite Minerals Pty. Ltd.	87	....	87	84	....	84
Western Mineral Sands Pty. Ltd.	39	....	39	41	....	41
Westralian Oil Ltd.	64	....	64	62	....	62
Western Titanium N.L.	115	....	115	139	....	139
Nickel—						
Western Mining Corporation	168	21	189	248	155	403
Petroleum—Crude Oil—						
West Australian Petroleum Pty. Ltd.	229	....	229	185	....	185
Pyrites—						
§Norseman Gold Mines N.L.	75	36	111	32	8	40
	2,846	512	3,358	3,148	599	3,747
All other minerals	437	28	465	369	7	376
State Total (Other than Gold)	3,823	540	3,823	3,517	606	4,123

* For details of individual years prior to 1967—see Annual Report for 1966 or previous reports.
† Effective workers only and totally excluding non-workers for any reason whatsoever.
§ Ceased production in June, 1968.

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